The Role of Engineers in the Creation of Engineering Drawings-Past, Present and Future

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Abstract - A change in technology can redefine roles in society. Skills that were previously considered specialties and/or optional can become required for the general population. Some recent examples include typing and drafting. Neither skill was expected from engineers before the widespread availability of personal computers. Secretaries performed the overwhelming majority of typing, and drafting technicians were available in sufficient numbers to do the drafting. Both were considered necessary support personnel in all engineering organizations. Recently, however, the adoption of personal computers has made typing and drafting expected and necessary skills for every engineer. The reason is that the number of typists and designers have decreased steadily during the last 20 years as engineering organizations reaped the benefits of the investment in personal computers that increased workforce efficiency. Some of the reduction in support personnel can be explained by increased efficiency but, in addition, today most engineering organizations expect engineers to perform tasks previously assigned to support personnel.

One implication of decreasing numbers of drafting technicians is that, increasingly, recent engineering graduates are expected to perform in such a role without the benefit of lengthy on-the-job training, while simultaneously learning to apply other traditional engineering skills such as analysis and project management. Engineering students can benefit by learning and practicing the skills traditionally associated with designers, namely, the production of engineering drawings. This requires more than learning to use computer aided design (CAD) software. In addition, the students must have a good understanding of drafting practices and standards and they must be able to write callouts for materials and commercial items in the correct format.

This report is a study of employment data from the past 100 years. The data appear to indicate that typing and drafting duties are transitioning from specialized support employees to the general population of engineers.

I. Introduction

Fifty years ago, the typical engineering department employed, in addition to the engineering staff, support personnel that included designers, detailers, checkers and a typing pool. Since then, technological advances have changed the composition of engineering organizations and what is expected from the engineering staff. The word processor and the multipurpose desktop computer were introduced to replace the typewriter and resulted in unintended changes. The paradigm shift occurred when a desktop computer was allocated to each engineer. Initially, the intent was to automate calculations with spreadsheets, commercial software and simple Basic and/or Fortran programs, but word processing was a natural consequence. Today, typing is an expected and required skill for all engineers.

The dramatic reduction in the cost of computers and computing encouraged the replacement of earlier computers with more powerful models every few years. One justification for new desktop computers is always the need to run the newest and most powerful software, and most recently, the need to facilitate communication and collaboration. This constant need to upgrade during the last 25 years, and especially during the last 10 years has resulted in desktop computers that are powerful enough to run sophisticated computer aided design (CAD) and solid modeling software.

Initially, simple CAD software merely automated the drawing of lines and was seen as a replacement for drafting boards, but drafting was still the responsibility of designers and detailers. Newer software can create a realistic solid model of a part or assembly. In addition, modern solid modeling software is integrated with other conceptualization and analysis tools such as visualization and finite element modeling (FEM). It has been embraced by engineers and is used throughout the design process from early concept generation through the analysis phase and in final detail design and beyond, including manufacturing, assembly and maintenance.

This study evaluated employment data published by the U.S. Bureau of Labor Statistics to learn if the observations noted above resulted in changes in the composition of the workforce.

II. Telephone Operators and Typists

Before investigating the impact of technology on drafting and drawing production, it is useful to look at similar transitions in the recent past. Two examples are the effect of technology on telephone operators and on typists. Figures 1 and 2 show the number of telephone operators from 1900 to 2001 and the number of typists from 1972 to 2001. Before 1972, information about typists was reported as part of "secretaries, stenographers and typists", and is shown in Figure 3. The recent trend is negative for telephone operators, typists and secretaries. Even as the total U.S. workforce expands between 1970 and 2001 in Figure 4, the number of telephone operators, secretaries and typists decreases.

The number of telephone operators peaked in 1970 at 421,000 (see Table 1). This date is just a few years after 7-digit direct dialing was introduced in the 1960s [1]. The trend was accelerated by the introduction of VMX, an early voice mail system, in 1979 [2]. Today the trend continues with sophisticated voicemail systems that greet callers and direct them through multiple levels.

The number of typists was constant during the 1970s, but steadily decreased after that. This correlates with the introduction of the Wang word processor in 1976 [3,4] and the IBM desktop computer in 1981 [5]. Today, every engineer has a desktop computer equipped with word processing software and is expected to use it to write letters, reports and other documents. Typing skills are required for today's engineer.

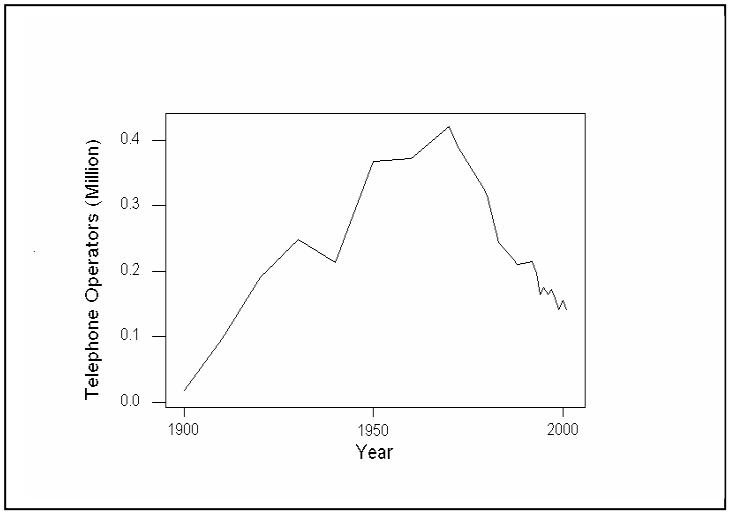

Figure 1 – Number of Telephone Operators in the U.S.

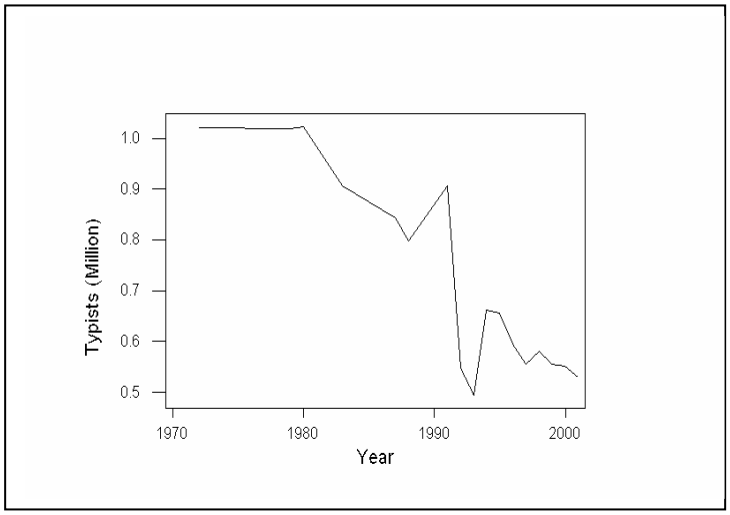

Figure 2 – Number of Typists in the U.S.

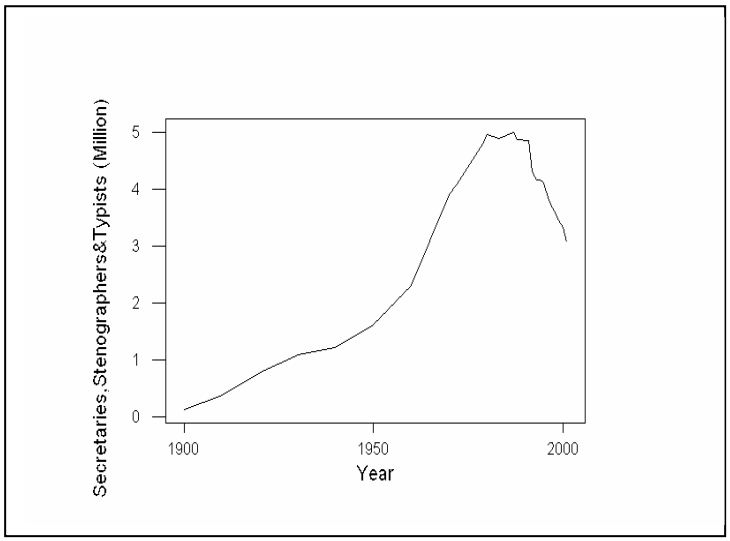

Figure 3 – Number of Secretaries, Stenographers and Typists in the U.S.

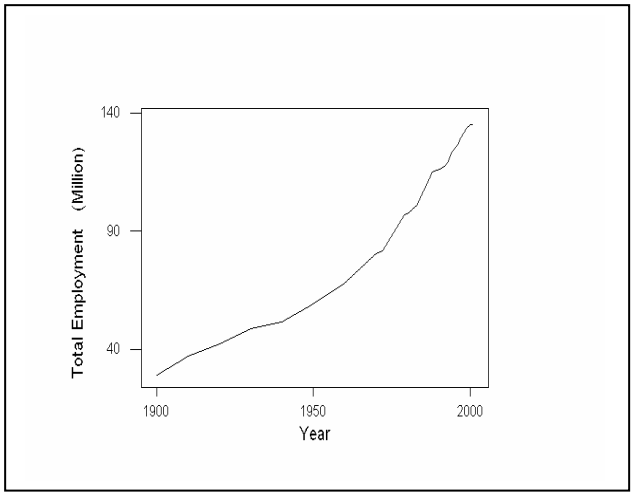

Figure 4 – Total Employment in the U.S.

III. Labor Saving Technologies

Seven-digit dial phones, voice mail and word processors were commercial successes because the labor saving potential they promised was real. They all required substantial investment that was scrutinized using financial analysis. After the investment was approved, management insured that the promised labor savings accrued either through layoff or attrition. Hence, the investment in relatively expensive VMX voice mail systems, Wang word processors and early desktop computers resulted in a reduction in the number of telephone operators, secretaries and typists.

From the experience in the twentieth century it can be safely concluded that, if the financial analysis determines that the new technology is cost-effective, its deployment is inevitable, irreversible and self-accelerating. Once a new technology is proven in one location, others will adopt it also. If the financial analysis uses labor savings as the justification, the new technology will disrupt the workforce by reducing the number of those workers responsible for using the new technology. An unintended consequence of this process is that other workers will be driven to assume some of the responsibilities of the displaced workers. For example, today's engineer initiates and answers telephone calls. Engineers also program the answering system with information about where they are and how they can be contacted when absent. These were tasks previously performed by telephone operators.

IV. Designers and Engineers

Figures 5 through 8 show the number of engineers, mechanical engineers, electrical engineers and drafting technicians. The number of engineers has been on the increase since 1900. This period includes the great economic depression of the 1930s. On the other hand, the number of drafting technicians peaked in 1980 and has been decreasing since then. Like telephone operators and typists before, drafting technicians appear to be in the process of being replaced by technology. The process started in the 1970s when the first CAD systems, using proprietary hardware, reached the marketplace [6]. The process continued through the 1980s with the introduction of desktop computers and Autocad software, and continues today with the accelerating reduction in the cost of computing and the increasing capabilities of CAD software.

The investment in early CAD systems was justified in terms of labor reductions, either by layoffs or through attrition. Next, the reduced number of drafting technicians drove the engineering staff to assume some of the responsibilities previously performed by designers and drafting technicians. Increasingly, engineers are expected to perform the early concept design work and layouts that in the past were done by the senior designers on the drafting staff. If the trends observed for the telephone operators and typists apply, the number of drafting technicians will continue to decrease and engineers will continue to assume their duties. This could result in increasing emphasis on traditional drafting skills such as dimensioning, specification of tolerances and of surface finish, and knowledge of drafting practices and standards.

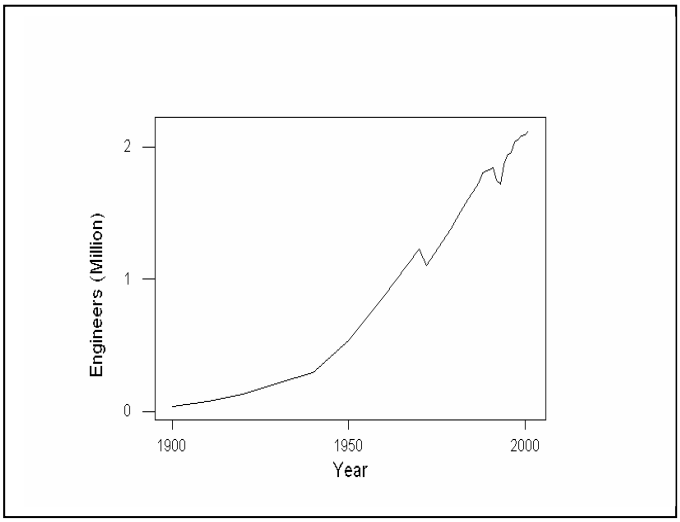

Figure 5 – Total Number of Engineers in the U.S.

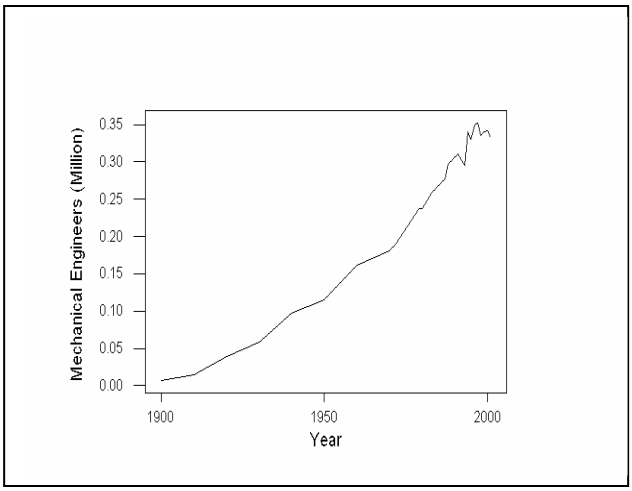

Figure 6 – Total Number of Mechanical Engineers in the U.S.

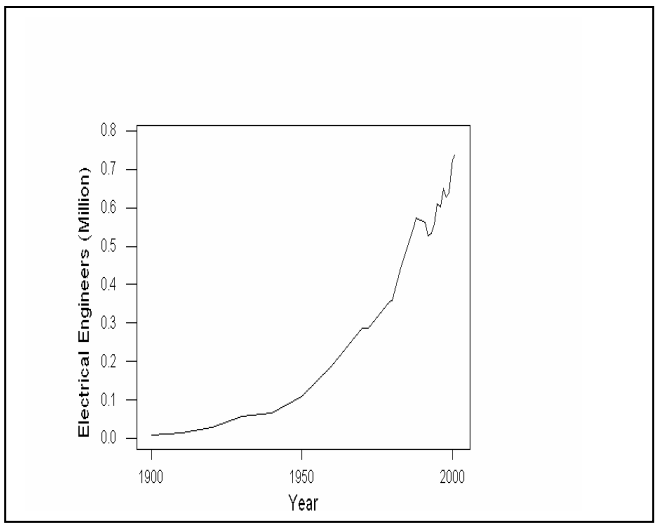

Figure 7 – Total Number of Electrical Engineers in the U.S.

V. The Role of 21st Century Engineers in the Production of Engineering Drawings

It is reasonable to forecast that, during the early part of the 21st century, engineers will increasingly assume many of the duties of designers and drafting technicians. Presently, engineers are expected to perform conceptual and layout design. In the future, engineers will also be expected to follow applicable

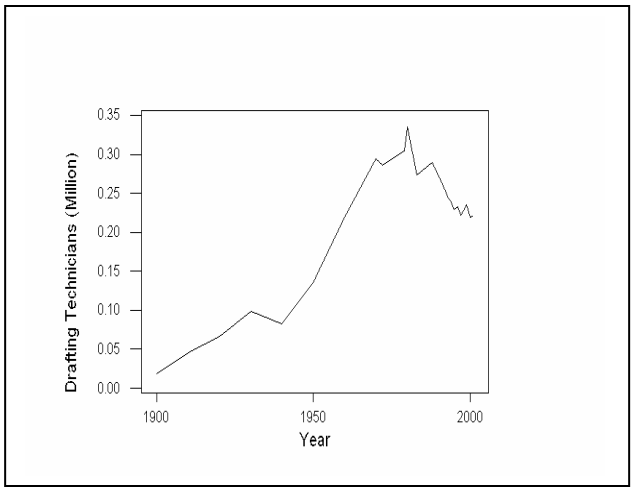

Figure 8 – Total Number of Drafting Technicians in the U.S.

standards to specify dimensions, tolerances, and materials and finish specification and callouts. This could result in renewed emphasis on drafting skills. Acquiring this knowledge will be important for new graduates because they will be expected to produce engineering drawings without a long apprenticeship period or the tutelage and advice of the drafting staff. The widespread use of solid modeling CAD has not eliminated the need to use drafting standards and conventions properly. In fact, today's CAD database contains more information than pre-CAD drawings and is most efficient if the creator of a new part input all the information needed. Increasingly, it will be the engineers creating early concepts who will also specify all the information required for detail design.

VI. Significance for the Engineering Curriculum

Some of the knowledge required to produce engineering drawings is part of the junior and senior years of the engineering curriculum. This includes courses such as materials and metallurgy, manufacturing process and design synthesis. On the other hand, drafting skills are taught relatively early in the engineering curriculum. Unfortunately, after the introductory CAD course, students are not required to continue demonstrating knowledge and competence in applying drafting practices and are not encouraged to integrate the knowledge they acquire in their junior and senior years into their drafting style. Students and newly graduated engineers can benefit if the emphasis on drafting practices is maintained until graduation.

VII. Conclusions

1. If the economic justification for implementing a new technology is increased labor efficiency, the number of specialist workers that used the technology originally will decrease over time.

2. Once the number of specialist workers starts decreasing, the trend is irreversible, as long as technological advance continues.

3. The reduction in the number of specialist workers will drive those that relied on their support to adopt the new technology and develop competence. The new technology will become a competency for all and not just the original specialists.

4. The implementation of CAD in the U.S. has resulted in a decrease in the number of drafting technologists and is changing the competency expectations for engineers.

5. Increasingly, engineers will be expected to be competent in the use of drafting standards and conventions.

6. Engineering students will benefit if drafting skills continue to be developed in their materials, manufacturing and design synthesis courses.

VIII. References

[1]http://www.privateline.com/TelephoneHistory3A/numbers.html
[2]http://www.everyvoicemail.com/vm-history.htm
[3]http://www.hnf.de/museum/textverarbeitung_en.html
[4]http://www.hnf.de/museum/textverarbeitung_en.html
[5]http://inventors.about.com/library/weekly/aa031599.htm
[6] http://mbinfo.mbdesign.net/CAD1970.htm
[7] *Historical Statistics of the United States*, Bureau of Labor Statistics, U.S. Printing Press (1980).
[8] *US Census Bureau Statistical Abstract of the US*, U.S. Printing Press, (annual publication)

Table 1 – Employment in the U.S. 1900-2001

Year	Total (Million)	Exec. & Mgrs. (Million)	Secret. (Million)	Typists (Million)	Sec,Sten &Typists (Million)	Engineers (Million)	Mechanical Engineers (Million)	Electrical Engineers (Million)	Drafting Tech. (Million)	Electrical& Electronics Techn. (Million)	Eng. Technol& Technicians (Million)	Telephone Oper. (Million)	Source
1900	29.03	1.697			0.134	0.038	0.007	0.007	0.018			0.019	[7]
1910	37.291	2.462			0.387	0.077	0.015	0.015	0.045			0.098	[7]
1920	42.206	2.803			0.786	0.134	0.039	0.027	0.067			0.19	[7]
1930	48.686	3.614			1.097	0.217	0.058	0.058	0.098			0.249	[7]
1940	51.742	3.77			1.223	0.297	0.097	0.065	0.082			0.214	[7]
1950	59.232	5.096			1.629	0.535	0.115	0.108	0.136			0.367	[7]
1960	67.99	5.708			2.316	0.871	0.162	0.188	0.219			0.372	[7]
1970	80.603	6.224			3.92	1.231	0.181	0.286	0.295			0.421	[7]
1972	81.702	8.031	2.949	1.021	4.095	1.102	0.191	0.287	0.286	0.164	0.828	0.392	[8]
1979	96.945	10.516	3.729	1.02	4.825	1.385	0.237	0.356	0.305	0.251	1.039	0.327	[8]
1980	97.27	10.919	3.876	1.023	4.963	1.433	0.237	0.357	0.335			0.316	[8]
1983	100.834	10.772	3.891	0.906	4.891	1.572	0.259	0.45	0.273	0.26	0.822	0.244	[8]
1987	112.44	13.316	4.107	0.843	5.004	1.731	0.277	0.545			0.896	0.218	[8]
1988	114.968	14.216	4.03	0.798	4.876	1.806	0.297	0.573	0.29	0.322	0.93	0.21	[8]
1991	116.877	14.954	3.891	0.906	4.861	1.846	0.311	0.562	0.264	0.35	0.947	0.213	[8]
1992	117.598	14.767	3.7	0.547	4.315	1.751	0.303	0.527	0.255	0.33	0.92	0.215	[8]
1993	119.306	15.376	3.586	0.494	4.174	1.716	0.296	0.533	0.244	0.297	0.87	0.197	[8]
1994	123.06	16.312	3.397	0.661	4.163	1.866	0.341	0.556	0.239	0.316	0.916	0.165	[8]
1995	124.9	17.186	3.361	0.656	4.106	1.934	0.33	0.611	0.229	0.334	0.88	0.176	[8]
1996	126.708	17.746	3.164	0.595	3.868	1.96	0.35	0.601	0.233	0.361	0.919	0.164	[8]
1997	129.558	18.44	3.033	0.555	3.692	2.036	0.352	0.652	0.222	0.391	0.96	0.173	[8]
1998	131.463	19.054	2.914	0.58	3.599	2.052	0.335	0.629	0.228	0.431	0.97	0.159	[8]
1999	133.488	19.584	2.781	0.556	3.457	2.081	0.34	0.639	0.235	0.437	0.973	0.142	[8]
2000	135.208	19.774	2.623	0.551	3.328	2.093	0.342	0.725	0.219	0.468	1.002	0.156	[8]
2001	135.073	20.338	2.404	0.529	3.086	2.122	0.333	0.739	0.22	0.475	1.007	0.14	[8]