On the Initiation and Development of an Advanced Manufacturing Educational Program to Aid Displaced Workers

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Abstract

This paper presents a model based on classic project management and systems analysis that was created and utilized by the University of Pittsburgh Department of Industrial Engineering Manufacturing Assistance Center (MAC) to develop an accelerated manufacturing training program for displaced workers. The following details the motivation for this initiative, how the curriculum was developed, and the design and implementation tasks. Results of two sessions, including a follow-up on subsequent job placement, are presented. The paper concludes with a discussion of future enhancements to the program and suggestions for extending the model into other types of training.

1. Introduction

Renowned management consultant and author, Peter Drucker[4] reported that the cost of higher education has risen as fast as the cost of health care, without any visible improvement in either the content or the quality of education. Thus, the U.S. educational system is being challenged to provide increased educational opportunities without the usual increases in budgets. When institutions of higher learning listen to the customer, i.e., the student, to help direct new strategic initiatives in this area, perhaps the most startling observation that they will make is a marked change in the customer. *Traditional* college students (age 18-22 and full-time) are slowly being outnumbered by *nontraditional* college students. Tucker[9] reports that today 40-50% of college students are busy adults, i.e., they are older, wish to attend school part-time, and have limited time due to work and family responsibilities. Schools that have recognized this trend have had success when implementing initiatives such as degree completion programs and continuing education courses aimed at this growing population of nontraditional students.[6]

The University of Pittsburgh's Manufacturing Assistance Center (MAC) developed and conducted an eight-week 300-hour advanced manufacturing technology educational program aimed at training a focused segment of these nontraditional students - displaced workers - with the skills necessary for an entry level machining position. This paper will describe the motivation for this initiative, how the curriculum was developed based on a regional survey and benchmarking analysis, and how the final course was designed and implemented. Since its development, two sessions with six students each have been conducted. Results of these sessions, including a follow-up on subsequent job placement, will be described. The paper will conclude with a discussion of future enhancements to the program and suggestions for extending the model into other types of training.

2. Background

2.1 The Manufacturing Assistance Center

The Manufacturing Assistance Center (MAC) is an initiative of the University of Pittsburgh's Department of Industrial Engineering. It is a 39,000 square foot technology transfer center equipped with a highly skilled staff, training rooms, a computer laboratory, and a working, state-of-the-art factory. The center houses a 5-axis wire EDM (electrical discharge machine), a 4-axis die sink EDM, a 2-axis CNC (computer numerical control) turning center, a 3-axis CNC machining center, various CAM (computer aided manufacturing) software packages, and inspection and testing equipment. The MAC also has a manual machine shop that consists of three lathes (16" x 30", 17" x 42", and a small tool room lathe), three 9" x 42" vertical mills, three surface grinders, a drill press, and a band saw. Southwestern Pennsylvania manufacturers have access to these machine tools and software systems on a shared basis, i.e., via a small hourly rental fee, and can also receive hands-on training. The MAC's mission is to assist regional manufacturers in gaining a competitive advantage in this global economy via the use of advanced, state-of-the-art manufacturing technology. Its four core services include shared manufacturing, training, technical assistance, and research/educational development. Previous to this program, the major training efforts were directed towards experienced technicians seeking to upgrade their skills in advanced manufacturing technology.

2.2 Motivation for the Program

From the late 1970's to the early 1990's, the overall manufacturing situation in the southwestern Pennsylvania area had been in serious decline. For the period between 1979 and 1985, over 40 large industrial plants permanently ceased operations. Between 1970 and 1990, the region lost 156,750 manufacturing jobs – more than half of the existing base of manufacturing jobs.[1] The region's population declined to 2,597,833 from 1980 to 1990 – a loss of 183,894 people.[3] Starting in the 1990's, regional manufacturing slowly began to improve. Manufacturing employment remained stable in 1994 and 1995, following declines from 1988 to 1993,[10] and now provides about 17% or 134,600, of the jobs in the six-county metropolitan region surrounding Pittsburgh.[5]

The main technical trades in manufacturing are classified as machinists and tool and die makers. Machinists utilize their knowledge of the working properties of metals, ability to read part prints, and skill with lathes, mills, and drill presses, to plan and machine products to meet precise specifications.[7] Tool and die makers are highly skilled workers who produce tools, dies, jigs, and holding devices that are used in various types of machines such as stamping presses, brakes, shears, extrusion machines, mills, and lathes.[8] Both occupations require competence in mathematics, blueprint reading, drafting, analytical reasoning, and excellence in machining. In 1994, machinists held about 376,000 jobs[7] while tool and die makers accounted for 142,000[8] throughout the United States. Median weekly earnings of machinists were about $520, where most earned between $420 and $690, the lowest 10% earned less than $300, and the top 10% made more than $880.[7] Median weekly earnings of tool and die makers were about $660, where most earned between $490 and $860, the lowest 10% earned less than $380, and the top

10% made more than $1130.[8] In addition to pay, most workers receive health and life insurance, a pension plan, paid vacations, and sick leave.

Despite the increasing use of automation and CNC, job opportunities are abundant for these trades. The majority of jobs are concentrated in the Midwest and Northeast, the location of many metal working industries,[8] and the forecast remains optimistic into the next century. In 1994, about 30% of tool and die makers were 50 years or older.[8] As older workers leave this trade, pronounced shortages are expected due to the decreasing supply of younger adults trained in this field.[8] Manufacturers throughout the nation report difficulties attracting workers to these occupations and finding qualified applicants. The National Tooling and Machining Association (NTMA) recently reported an estimated 24,000 vacancies in the United States, some with a pay rate of more than $20 per hour.[2] Regional manufacturers have echoed this sentiment to the MAC. As the influence of larger companies decreased in southwestern Pennsylvania, so did their extensive apprenticeship programs, which provided a pipeline of skilled machinists to the area. Upon closer examination, it is estimated that of the 415 tooling and machining shops in western Pennsylvania, an estimated 1,000 journeyman machinists could immediately be employed at positions that typically pay between $30,000 to $60,000 a year.[5]

3. Methodology

In an effort to fulfill the strategic employment needs of regional manufacturers, the MAC embarked on a mission to best utilize the existing state-of-the-art manufacturing center to train people interested in machining/tool and die making careers. The major steps taken followed basic systems analysis. The needs of local manufacturers were assessed, objectives and goals of the program were defined from these needs, then a team was assembled to define, assign, budget, schedule, and execute the various tasks to develop this program through the use of classical project management techniques.

3.1 Needs Assessment

The preferred employees sought by southwestern Pennsylvania manufacturers are experienced, journeyman machinists or tool and die makers. Pennsylvania's journeyman certification is an extensive four year program consisting of classroom theory and 8,000 hours of hands-on machining for a manufacturer. The qualification of the MAC as a learning institute and not a manufacturer, coupled with limited MAC resources and funding, constrained the use of the facility for journeyman certification. An informal survey of 25 local NTMA companies revealed to the MAC a willingness on the part of manufacturers to train entry level machinists / tool and die makers *off the street* for this certification if they were *serious* about the trade. Though entrance tests used by these manufacturers provided some success in screening applicants, they sought assistance in avoiding wasting training resources on those individuals who would leave the trade after realizing it was not the career for them.

The skills for entry level applicants most commonly expressed to the MAC are the ability to read blueprints, utilize basic geometry and trigonometry in solving machining problems, and read and use measurement gages. Preferred machining skills depended on the predominant process of the manufacturer. The list included surface grinding, manual mill and lathe, welding, computer numerical control machining, and electrical discharge machining. Besides technical skills, local manufacturers seek a battery of softer skills, such as responsibility and reliability (e.g., show up to work on time when scheduled), maturity, accountability, and a good attitude from potential candidates. It was suggested to the MAC to make potential new hires aware of the new image of manufacturing (i.e., clean, temperature controlled environments), the career options for a machinist/tool and die maker, the typical working hours (average of 50 hours per week), and demands on precision and quality. Finally, it was important that individuals starting out in these trades understand that beginning pay rates will be low (between $7 and $8 per hour) to offset the training investment of the company, and will increase to journeyman rates over an extended period of time (3 to 6 years on average) based on the proven performance of the employee.

3.2 Strategy

Since there was an immediate need by regional manufacturers for good entry level persons, the MAC explored potential candidates within the ranks of displaced workers. In January 1996, the unemployment rate in the Pittsburgh area was at 6.3% or 70,700[10] and based on contact with regional job training funding agencies, money was available to assist this group. After synthesizing input from manufacturers and job training funding agencies, the MAC team proposed an accelerated eight-week 300-hour program to produce highly skilled entry level candidates for local manufacturers from the pool of displaced workers. The length of the program, eight weeks, was recommended by the job training funding agencies based on the limited time of unemployment benefits for the average displaced workers and the fixed amount of funding that could be covered by the agencies. The program emphasized blueprint reading, mathematics, use of gages, and basic materials science, and covered the theory of a variety manufacturing technologies, reinforced with extensive hands-on projects. The technologies included manual milling, lathe, surface grinding, CNC machining and turning, CAM, and EDM. The wide selection of technologies was chosen to provide the student with as many job opportunities as possible upon graduation. Welding was not included due to time constraints and the unavailability of this technology at the MAC. The combination of manual and automated machines was employed to provide students with an understanding of the basics of machine tools and the future requirements for machinists and tool and die makers.

Given the content, the accelerated nature, and the limited time frame of the proposed program, the MAC used the following strategies during the design and implementation of this program. The first was to establish an integrative and parallel training curriculum. For example, since blueprints, math, and gage reading are used everyday by machinists and tool and die makers, these concepts would be covered in theory early in the program and practiced simultaneously during the shop floor projects throughout the eight weeks. Thus, at the end of the program, the student would have up to eight weeks of extensive hands-on experience integrating the major concepts. The MAC concentrated on the careful selection of students through interview and testing methods. During the interviews the MAC explained to the students began what to expect from the training, the entry level positions and types of companies seeking employees with this training, and the expected starting wages. Because the content of the curriculum was very extensive, the student to teacher ratio was kept low (e.g., each class had 6 students, and machining projects had 2 instructors). The MAC actively sought representatives from industry who would meet with the students and if possible mentor them throughout the program.

3.3 Program Development

To develop the program, the MAC team employed some basic techniques and practices of project management. Based on the assessment of manufacturers and agreed upon strategy, the team defined the major objectives and performance criteria for the training program and established a target budget and implementation time frame. The next step was to develop clear tasks that would provide the desired deliverables. This was accomplished via a work breakdown structure (WBS). A WBS graphically defines the tasks and their relationship to each other and the major project objectives, and establishes the resources necessary to fulfill them. It helps ensure that no major step is overlooked and that all team members are aware of the total work required to successfully complete the project.[11] Figure 1 represents the WBS used for this project. It includes segments common to many training programs, i.e., students, curriculum, facilities, materials, and oversight and measurement of the program, along with unique activities, such as placement and mentors. From the WBS, smaller, more manageable tasks were defined, traceable to the overall project objectives through high level, more general work segments. Each task was assigned to various team members, along with a clear definition of responsibility for completion, level of contribution, and approval. The tasks were then budgeted and scheduled based on precedence and the availability of resources (human, physical, and monetary). The Meetings were scheduled on a weekly basis throughout the development to track effort and performance towards completing the tasks, address problems, and make any necessary corrective action. The MAC presented a preliminary curriculum to the local NTMA members at their January 1997 monthly meeting and subsequently met with four manufacturing companies at the MAC to review the program before the first class. These simple procedures assisted the project team in tracking and controlling team effort during the program development such that the stated objectives were reached within a reasonable time frame and budget.

4. Final Program Design

The final program curriculum is shown in Figure 2. The program was first suggested by the MAC's training coordinator in late June 1996 and the first class began May 12, 1997. It has been refined throughout the two sessions that have been conducted to date. The flow of topics begins with the basics, with each new major concept building upon the previous. The program consists of two major parts, manual machining and computers in manufacturing. During the first week, the student is introduced to machine shop safety, blueprint reading, gage reading, and manual machine tool theory. This is accomplished through reading assignments, classroom lectures, demonstrations, videos, and hands-on tasks (e.g., using a micrometer, and turning handles on a machine). Each student has to pass a safety test before operating any major piece of machinery. The second week is split up into mathematics in the mornings and hands-on manual machining in the afternoons. Extensive reading and homework is assigned to augment the mathematics covered. All machining projects are graded on accuracy of final part dimensions to design, thus blueprint reading and use of gages are reinforced extensively within the machining projects. In week three, manual machining projects continue in the afternoons while the mornings are utilized for advanced math, the basics of science (e.g., material and cutting tool properties, setting feed and speed rates, and heat treating), and shop management concepts (e.g., fixed costs, variable costs, direct costs, and overhead).

- 1.0 Eight Week Advanced Manufacturing Program
  - 1.1 Students
    - 1.1.1 Contact and market services to funding agencies
    - 1.1.2 Develop profile of desired students
    - 1.1.3 Educate/interview potential students about program
    - 1.1.4 Develop entrance exams
    - 1.1.5 Test, assess, and select students
    - 1.1.6 Establish contracts between funding agencies and university
    - 1.1.7 Establish introduction process (fire routes, break areas, etc.)
    - 1.1.8 Establish alternatives for student transportation
  - 1.2 Curriculum
    - 1.2.1 Determine topics, course content, sequence of classes, and course materials
    - 1.2.2 Develop safety procedures for utilization of equipment
    - 1.2.3 Identify, select, contract, and develop instructors
    - 1.2.4 Develop hand-outs and identify, procure textbooks
    - 1.2.5 Develop testing devices (quizzes, final exams, hands-on testing)
    - 1.2.6 Develop and prove out class work (homework, hands-on projects)
    - 1.2.7 Schedule assessment meetings with industry
  - 1.3 Facilities
    - 1.3.1 Prepare / reconfigure floor plan
      - 1.3.1.1 Address / relocate power sources
      - 1.3.1.2 Setup and test machines
      - 1.3.1.3 Configure student work areas
    - 1.3.2 Schedule classrooms
    - 1.3.3 Schedule computer lab
  - 1.4 Materials
    - 1.4.1 Equipment (machines, computers, software)
      - 1.4.1.1 Define specifications
      - 1.4.1.2 Assess current capacity and condition
      - 1.4.1.3 Obtain additional equipment
        - 1.4.1.3.2 Solicit donations
        - 1.4.1.3.2 Procure new / used equipment
    - 1.4.2 Tooling (hand tools, vices, cutters, fixtures, etc.)
    - 1.4.3 Student assessories (gages, toolbox, calculators, etc.)
    - 1.4.4 Material for projects (bar stock, sheets, etc.)
  - 1.5 Placement and Mentors
    - 1.5.1 Develop student resumes
    - 1.5.2 Identify potential employers
    - 1.5.3 Schedule company tours
    - 1.5.4 Send resumes
    - 1.5.5 Coordinate interviews
    - 1.5.6 Host company representatives and guest speakers
  - 1.6 Oversight / Measurement
    - 1.6.1 Plan master budget (curriculum, materials, facilities, etc.)
    - 1.6.2 Plan master schedule (dates, instructors, topics, etc.)
    - 1.6.3 Track information required by contracts
    - 1.6.4 Monitor performance of students
    - 1.6.5 Solicit and compile feedback
    - 1.6.6 Monitor safety procedures
    - 1.6.7 Coordinate graduation ceremony and certificates
    - 1.6.8 Coordinate public relations efforts

Figure 1. Work Breakdown Structure for the Eight-Week Advanced Manufacturing Program

The second part of the program, computers in manufacturing starts in week four. During the first two days of week four, CNC theory and programming are covered via lectures, in-class exercises, and homework. After this, teams of two students are set up and rotate through CNC machining, CNC turning, and manual machining projects every two to two-and-one-half days up through week six. Teams are used due to the availability of only one CNC machining center and one CNC turning center at the MAC. It also allows students to gain appreciable experience in CNC machining while permitting them to continue advancing their skills in manual machining. The students have to develop and program the CNC machine by hand from blueprints during this period and continue to measure the final pieces via gages. In week seven, the students are taught the theory and uses of CAM, which combines the geometry of CAD drawings and software instructions to generate CNC programs. Projects consist of using CAM to generate CNC programs, loading them on CNC machines, and executing the program to produce a physical part. The final week is dedicated to EDM theory and hands-on projects. At the end of week eight, final program testing is conducted. A graduation ceremony is then coordinated to honor the students and funding agencies.

Wk		**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
1	AM	Introduction	Intro Shop Math	Blueprint Reading	Intro Hand Tools	Intro to Lathe
	PM	Safety	Intro to Gaging	Blueprint Reading	Intro to Milling	Intro Surf. Grinding
2	AM	Decimals Fractions	Measurements	Graphs, ratios, shop functions	Powers, roots, geometry	Trigonometry
	PM	Manual machining	Manual machining	Manual machining	Manual machining	Manual machining
3	AM	Trigonometry	Materials, spark and hardness test	Cutting tools, speeds & feeds	Heat treat and demonstrations	Shop Management
	PM	Manual Machining	Manual machining	Manual machining	Manual machining	Manual machining
4	AM	CNC Theory	CNC Theory	CNC / manual machining	CNC / manual machining	CNC / manual machining
	PM					
5	AM	CNC / manual machining	CNC / manual machining	CNC / manual machining	CNC / manual machining	CNC / manual machining
	PM					
6	AM	CNC / manual machining	CNC / manual machining	CNC / manual machining	CNC / manual machining	CNC / manual machining
	PM					
7	AM	CAM	CAM	CAM	CAM	CAM
	PM					
8	AM	EDM	EDM	EDM	EDM	Final Testing
	PM					

Figure 2. Final Schedule for the Eight-Week Advanced Manufacturing Program

5. Results

Table 1 summarizes the results of the two sessions. The first class, which ran from May 14, 1997 to July 3, 1997, will be referred to as Class A. The second class, which ran from September 2, 1997 to October 24, 1997, will be referred to as Class B. Students labeled with A (e.g., A1, A2, etc.) are from the first class and students labeled with B are from the second class.

All six students from Class A were classified as displaced workers. Five found employment after the program with a new employer and one was recalled by his original employer. Of these, four started new careers in tool and die companies and one, though offered two jobs in tool and die, chose a position as a sales person for a local machine tool vendor. One of the students in tool and die did not pass the company's evaluation after one month and was let go, but subsequently entered into another company's tool and die apprentice program. For Class B, five students were classified as displaced workers. The remaining student was sponsored by his current employer. Of the five displaced workers, two found jobs (one as a machinist, and one as a die setter apprentice) within two weeks of the program's end. Two students have each been called in for second interviews for machining related positions. One student left the program after three weeks for employment outside of manufacturing.

For Class B, the MAC tested students in each of the program's math concepts before and after the program to assess the performance of instruction. The two tests were identical and allowed only the use of pencil and calculators. The pretest was administered on day one of week one and the posttest was administered on day four of week eight. The MAC was pleased with the results and the progress of the students. Student B4 returned to the MAC upon graduation for additional math tutoring.

The overall grade consisted of the weighted averages of homeworks, quizzes, projects, math posttest (not pretest), and final exam scores. The final exam covered science, shop management, manual machining (both written and hands-on), CNC, CAM, and EDM.

Student	Age	Previous Occupation	Starting Wage	New Job Title	Math Pre-Test	Math Post-Test	Overall Grade
A1	45	Tool room attendant (steel company)	$ 8.00/hr	Precision grinder	N/A	N/A	96.8
A2	50	Metals lab technician	$ 7.50/hr	Precision grinder	N/A	N/A	97.9
A3	42	Lathe operator (steel company)	$ 7.50/hr	Precision grinder	N/A	N/A	93.2
A4	47	Self employed	$ 8.50/hr	EDM Operator	N/A	N/A	88.8
A5	36	Mill operator (steel company)	$ 25,000/yr	Equipment Sales	N/A	N/A	95.9
A6	42	Laborer	$15.00/hr	Recalled to job	N/A	N/A	91.6
B1	35	Machining supervisor	N/A	Currently employed	76.1	97.3	96.7
B2	35	Assembler (doors)	$ 7.50/hr	Delivery / Mgt.	60.6	*	*
B3	38	Mold shop apprentice	$ 7.50/hr	CNC Operator	57	91.3	91.3
B4	47	Warehouse worker	**	**	46.1	54.6	72.9
B5	42	Farmer	**	**	61.1	96.4	94.8
B6	42	Printer	$ 8.00/hr	Die Setter Appr.	68.4	98.1	95.6

* student dropped out of the program ** currently interviewing for positions

Table 1. Student Background and Results for the Two Classes Conducted

The aspect of mentoring has yet to take shape. Though many shops were invited to view the students working and/or interview them at the MAC during the program, none accepted. However, many companies requested resumes during the program, some as early as week three, and roughly half the students from each class were interviewed for positions before the end of the program. One student from Class A received a job offer before the end of the program. No shop volunteered to mentor any of the students in either class. Class A had three guest speakers, each from three separate local NTMA shops, and visited two NTMA shops. Class B had three guest speakers, each from three separate local NTMA shops, and visited one NTMA shop.

6. Conclusions

The MAC is pleased with the placement of students in promising machining and tool and die jobs. The program is too new to assess the long term results of these placements. The students have confided to MAC management a general displeasure with, but understanding of, the starting wages, though it was adequately explained to them before entering the program. Hopefully in later classes, the MAC can invite former students who will be making better wages at that time to discuss this issue with the then current group of students.

With regards to the student who did not pass the new employer's evaluation, it was brought to the attention of the MAC that it was not skills related, i.e., the student's level of technical competence was not questioned. The MAC viewed the situation in which the student who left the second program as meeting the objectives of the program by saving a local company the cost of training an individual who did not want a career in machining. However, due to this, the MAC will continue to evaluate and update its own screening process for this program. Perhaps with two classes successfully completed, local companies will gain confidence in the program and offer to mentor students in upcoming classes.

What is proposed in this paper is a model to provide continuing education to a market segment which is perhaps not considered to be mainstream. The program is successful because it generates additional revenue for the institution without significant increases in costs; it provides educational opportunities to a population of students that otherwise would not have come to the University of Pittsburgh; it builds alliances with local small manufacturing firms who send their employees to this program and/or hire students who complete this program; it provides networking opportunities between engineering students with the program's students; it allows for a better understanding of the demands and capabilities of future manufacturing teammates, i.e., engineers and machinists; it capitalizes on a strength area of the School of Engineering, namely its MAC; and it better utilizes the existing resources - people, equipment, and facilities. It represents a win-win opportunity for all. This model can be easily extended into other careers and forms of training that match more closely with the strengths and needs of your institution.

Future plans are to expand this model at the University of Pittsburgh. This expansion includes offering the current eight-week training program to a wider population of students and developing other manufacturing training courses. New courses could be in the form of follow-on training for those completing the current eight-week training program, or developing other introductory training programs. The University of Pittsburgh will work closely with local businesses and trade associations to make this final determination. One initiative that is underway is the development of a 24-hour pilot course for working engineers. This course is a scaled-down version of the manual machining portion of the eight-week training program.

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