A New Educational Paradigm to Train Skilled Workers With Real World Practice

Dr. Juan Song, Alamo College

Dr. Juan Song is Corporate Account Executive in Alamo College at San Antonio, TX. She oversees secondary and post-secondary training in manufacutring and liaison between Alamo College and manufacture partners. She is also the coordinator for Toyota Advanced Manufacturing Technology(AMT) Program and the AMTEC-ATE liaison.

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Juan Song[1], Maurice Salazar[2], Mary Batch[2], Colin Nichols[1] and Federico Zaragoza[1]

1. Corporate College, Alamo Community College, San Antonio TX 78211
2. Toyota Motor Manufacturing, Texas, Inc. San Antonio TX 78264

Abstract

Skilled labor is at crisis-level shortages both at home and abroad, with over 10 million skilled labor jobs remaining vacant worldwide. This shortage is not likely to abate in the near term, but rather get significantly worse. A global study by McKinsey & Company predicts a need for 95 million skilled workers by 2020. Currently, studies showed that more than 80% of manufacturers in the U.S. struggle to find qualified multi-skilled workers. Due to rapid technology development and decreased engagement between our education system and manufacturers, the U.S. community college system is not providing globally competitive technicians. These technicians lack both state-of-the-art practical experiences in manufacturing and a foundation in manufacturing education. With the engagement of one of the largest automotive manufacturers in the world, Toyota, our Advanced Manufacturing Technician (AMT) program provides a new paradigm to redefine the relationship of students, higher-education and the manufacturing industry. Our program focuses on training the "technician" (the person) in addition to the "technology"-- though there is more technology involved than most traditional programs. In partnership with Toyota, we established a special "manufacturing area" to provide a more realistic workplace environment. Our curriculum has been designed to help students obtain a two-year Associate Technical Degree that combines cutting-edge manufacturing technology, paid working experience and hands-on education. The biggest improvement that differentiates the other programs is the hands-on experience - being able to go to work the next day and have hands-on practice with what they learned in class. As such, the graduates can bypass several years of on-the-job training to readily fill advanced positions in manufacturing. In addition, students learn business principles and best practices from a world class manufacturer known to deliver products high in safety and quality. This work-in-progress program will ensure a sustainable supply of skilled workers to maintain a globally competitive workforce in the U. S. manufacturing industry.

Motivation

Skilled labor is at crisis-level shortages both at home and abroad, with over 10 million skilled labor jobs remaining vacant worldwide [1], and up to 600,000 positions in American manufacturing companies [2]. That shortage is unlikely to abate in the near term. A global study by McKinsey & Company predicts a need for 95 million skilled workers by 2020, while simultaneously anticipating a surplus of low-skill workers that reaches the same heady number. Currently, studies show that with 67% of manufacturers reporting a moderate to severe shortage of available, qualified workers and 56% anticipating the shortage to grow worse in the next three

to five years [4]. In addition, study also indicates that 5% of current jobs at respondent manufacturers are unfilled due to a lack of qualified candidates [4]. Therefore, it is critical to figure out one way to provide sustainable and competitive workforce for the global manufacturing market.

To solve the skilled worker shortage, a community-based approached is needed in manufacturing education by creating strong partnerships between schools, businesses and organizations [5]. However, the academic infrastructure needed to educate and train a workforce with the knowledge and skills necessary to support manufacturing is in need of serious repair. It is imperative that manufacturing industry is working hand-in-hand with education to properly train and educate both our current and future workforce. For example, in addition to the traditional science-based theory courses in most academic programs [6], practice-oriented experiences which can and should be included more with the current curriculum.

In this paper, we describe a DoL-funded Advanced Manufacturing Technician (AMT) program aiming to lead and drive the change in traditional education in manufacturing to enable the manufactures to achieve a globally competitive workforce to fill the skilled labor gap. Compared to previously reported program, there are at least two advantages in our approach. First, real-world experiences is extensively integrated into the curriculum, allowing technical workers to bypass several years of on-the-job training. The skilled graduates will be more welcomed by manufacturing partners as they are already trained and ready to fill advanced positions in manufacturing. Second, the students enrolled into the program are getting paid over the two-year program, essentially eliminating the need for most student loans. This is an attractive prospective to many students who struggle to finance their higher education.

Overview and Objectives

Advanced manufacturing in the U.S. has experienced a profound transformation over the last decades. Technology has become increasingly sophisticated, while the workforce with the correct skills has become increasingly lean. These two trends have met, and as a result, a high school diploma and stagnating skills are no longer sufficient to meet the needs of the industry. Workers must have technical skills that are continuously updated to keep pace with technology and rapidly changing production system parameters. These fast-paced technology and organizational changes are forcing advanced manufacturing employers to update their processes and tools to stay competitive in a global market and challenging them to find a sustainable way to prepare new skilled workers. Therefore, with the engagement of Toyota, one of the largest automotive manufacturers in the world, our AMT program provides a new paradigm to redefine the relationship among students, higher-education and the manufacturing industry. Furthermore, technology is critically important. As such, our program has a stronger emphasis on technology than most traditional technical programs.

The goals of our AMT programs included: (1) actively recruiting students with diverse backgrounds to engage in technology in manufacturing; (2) educating students about advanced manufacturing technologies needed in manufacturing field with cutting-edge/industrial-defined curriculum; (3) educating students soft skills, including interpersonal, communication, industrial technical writing, and natural teamwork skills, etc; (4) providing students with paid working experience and hands-on education; and (5) providing a globally sustainable and competitive workforce.

With the engagement of the largest automotive manufacturers in the world, students enrolled in this program will study in the college for two full days/week coupled with work of 3 days/week in Toyota. They will earn a wage while attending college and gain priceless work experience with a global manufacturing leader. Over two years, students can earn as much as $30,000 in salary, which with planning can cover all of the education expenses. After two years study, the students will get an associate technical degree.

Students Recruitment and Selection

The AMT program targeted high school students who (1) have enthusiasm and interests in manufacturing technologies; or (2) belong to groups that are traditionally underrepresented in technology, including women. Flyer advertisement and face-to-face workshops were conducted to approximately 25 high schools around greater San Antonio area. Campus visits were scheduled to meet with faculty and students in classes and at student professional organization meetings. Along with the Alamo Colleges application for admission, Toyota's personnel are involved in selecting highly potential students on the following criteria:

- Academic success as measured through grades/transcript.
- Math capability as measured through ACT, SAT or accuplacer.
- Participation is preferred in one or more STEM focus programs: Alamo Academies Advance Technology & Manufacturing Academy (ATMA), First Robotics, Pre-Freshman Engineering Program (PREP), Project Lead the Way (PLTW)
- Must pass illegal drug test.

The admission to the AMT program is highly competitive. All the candidates were first contacted via a telephone interview and qualified candidates were further followed up by onsite interview during campus visit. Finally, Finally 20 applicants were selected to be enrolled into this current program started from Fall 2013.

General Program Information

As described earlier, the AMT program's goal included: (1) educate students about advanced manufacturing technologies needed in manufacturing field with cutting-edge curriculum; (2) educate students soft skills, including interpersonal, communication, and natural teamwork skills; (3) provide students paid working experience and hands-on education; (4) provide a

globally sustainable and competitive workforce. To achieve these goals, the following activities have been conducted:

Vision the final product

In order to meet the global competiveness in workforce, our target is to provide 100% of maintenance force which is totally multi-skilled in technologies with strong soft skills and problem-solving and hands-on skills. In order to achieve this target, first we have to define and establish the necessary skills for our skilled team member for next generation, as shown in Figure 1.

Figure 1. "where are we going"

Redesign the community college program

Manufacturing today is radically different from the manufacturing of yesterday. It is technologically sophisticated, lean-oriented and integrated around complex manufacturing systems. Manufacturing education has historically trained workers in a set of foundational skills that have grown increasingly disconnected from employer need; however this is no longer a viable solution. Instead, manufacturing education must respond to, and even anticipate industry skill need changes. Therefore, Alamo Colleges and Toyota have collaborated to redesign our current program to transform the development and delivery of manufacturing education to meet dynamic employer demand and improve student outcomes. Figure 2 shows skill standards for a two-year schedule plan for our AMT program. It covers all topics including general education, technical core areas, manufacturing experience, manufacturing core exercises and work behaviors within this period.

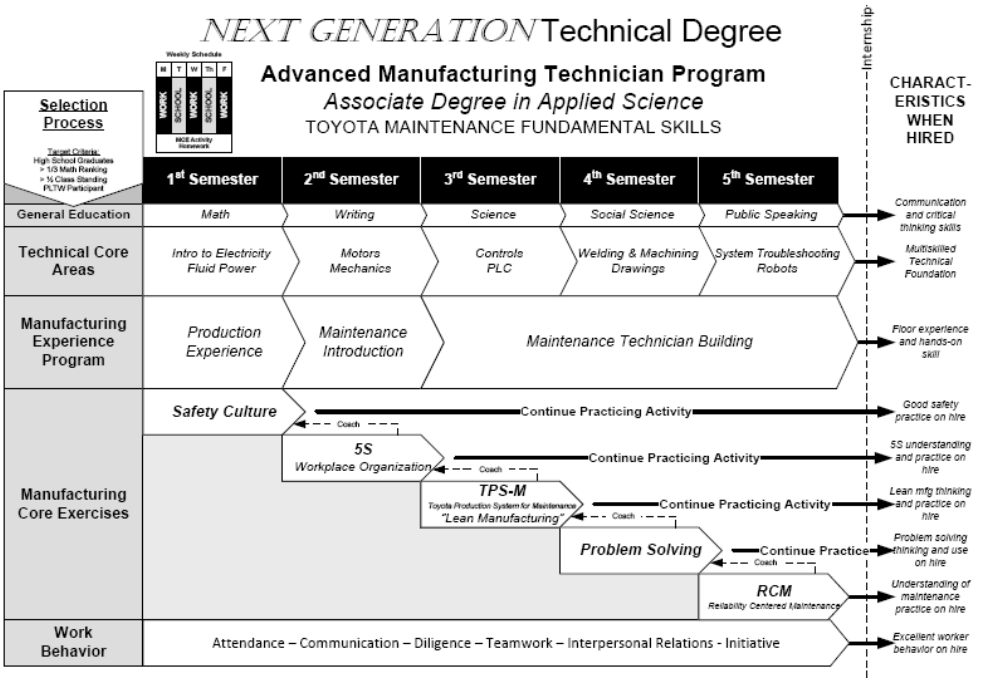


Figure 2. Maintenance fundamental skills for AMT program

Industry engagement to identify the standards and competencies

As mentioned earlier, most manufacturing programs provided by community colleges are greatly lagging behind the competencies needed in today's manufacturing employers- and colleges are unprepared to resolve the discrepancies. It is clear that colleges do not have the equipment and other learning technologies used in today's manufacturing plants to train workers; nor do they have the industry-driven, cross-skilling curriculum required by today's manufacturers. All these result in graduates who do not have the competencies to perform well in today's complex manufacturing organizations. In order to fill this gap, our AMT program is closely working with industry people to identify the standards and competencies needed, and then use those competencies to develop curricula and assessment. To make our program stronger and more competitive, we have utilized the NSF-funded the Automotive Manufacturing Technical Education Collaborative (AMTEC) process model which is dedicated to create nationally certifiable industrial maintenance mechanical training programs in partnership with area industries [7]. With the engagement of Toyota, we have developed our new competency-based curriculum. Figure 3 shows an example of AMTEC Core Skill Standards with which our AMT program is very closely aligned.

Redesign the learning environment

Unlike the traditional educational colleges, in which students take classes in individual classrooms, we transformed the place of learning to mimic the function of real workplace. All classes took place in open industrial-like environment, including classes of hydraulics, pneumatics, programmable logic controller, robotics, electronics, mechanics, motor control, and troubleshooting. Not only modern manufacturing process and technologies can be provided simultaneously, but also the students can get familiar with the industry environment, as well as to coordinate and work with different working groups. Therefore, students can learn the right way the first time. Figure 4 shows our new model school for AMT program, where not only the fundamental skills and classroom practices, but also safety and5S learning labs are conducted in the same environment.

AMTEC Core Skill Standards

	A		MECHANICAL EQUIPMENT
1		1	Troubleshoot/repair/replace brakes & clutches (electromechanical and mechanical)
2		2	Troubleshoot/repair/replace gears
3		3	Troubleshoot/replace belts, sheaves/pulley
4		4	Troubleshoot/maintain chains and sprockets
5		5	Troubleshoot/repair/replace cams
6		6	Troubleshoot/repair/replace seals and o-rings
7		7	Troubleshoot/repair/replace bearings and bushings
8		8	Troubleshoot/repair/replace shafts
9		9	Perform alignment and balancing
10		10	Troubleshoot/repair/replace motors (AC and DC)
11		11	Maintain couplings
12		12	Maintain fans
13		13	Install/maintain valves (cut-off, pressure relief...)
	B		PNEUMATIC/HYDRAULIC EQUIPMENT
14		14	Troubleshoot/repair/replace pneumatic/hydraulic valves
15		15	Troubleshoot/repair/replace cylinders and intensifiers
16		16	Troubleshoot/repair/replace hoses and tubing
17		17	Adjust pressures and flows mechanically and electronically
18		18	Maintain fluid levels for hydraulic systems
19		19	Replace filters on hydraulic/pneumatic systems
20		20	Troubleshoot/repair/replace gauges
21		21	Troubleshoot/repair/replace pneumatic/hydraulic pumps
22		22	Troubleshoot/replace accumulators
23		23	Troubleshoot/repair/replace air motors
24		24	Maintain vacuum system on pneumatic equipment
25		25	Maintain filtration systems
26		26	Adjust switches and controls on hydraulic/pneumatic system
27		27	Install/design hydraulic/pneumatic components to upgrade/enhance systems
	D		PREDICTIVE/CORRECTIVE MAINTENANCE
28		32	Perform route-based vibration analysis
29		33	Collect oil samples for analysis
30		34	Interpret and take action on oil analysis
31		35	Perform alignment (laser system)
32		36	Perform balancing
33		37	Perform online motor current analysis
34		38	Perform off-line motor current analysis
35		39	Perform infrared thermography
36		40	Perform ultrasonic maintenance
	E		BLUEPRINT READING/SCHEMATICS
37		41	Interpret mechanical drawings
38		42	Interpret pneumatic and hydraulic drawings
39		43	Interpret electrical schematics
40		44	Interpret piping and instrumentation diagram (P&ID)
41		45	Operate basic drafting software (AutoCAD or Visio)

Figure 3. Partial AMTEC Core Skill Standard

Figure 4. The new model school for manufacturing

Make every development minute count

In order to ensure 100% use of every learning minute either at school or on the floor, we redesigned our curricular program into straight 8 hours/day, 5 days/week for 5 straight semesters. Figure 5 (a) shows a student weekly schedule and Figure 5(b) illustrates a whole schedule for a two-year span. Students stay in college on Tuesday and Thursday from 7am to 5pm to strictly follow our developed curricula for each semester and work on the floor at Toyota on Monday, Wednesday and Friday. Every course for each semester is industry-driven and pre-selected for maximum preparation for advanced manufacturing. In addition, to ensure student engagement,

student attendance is tracked daily and reported weekly by the engaged faculties. Absence/late arrivals/early departures are reported immediately.

	One Week				
	M	Tu	W	Th	F
8-10 hr -	WORK	SCHOOL	WORK	SCHOOL	WORK
	Program work (1-2 hours)				
	Home Work & STUDY				

Figure 5 (a). Student weekly schedule

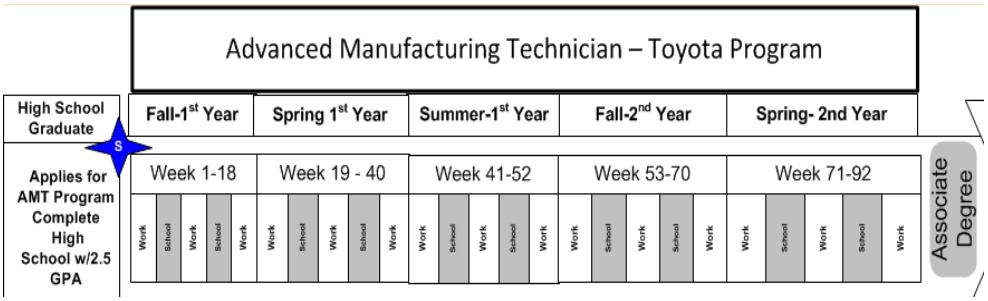


Figure 5 (b). Student schedule for a two-year span

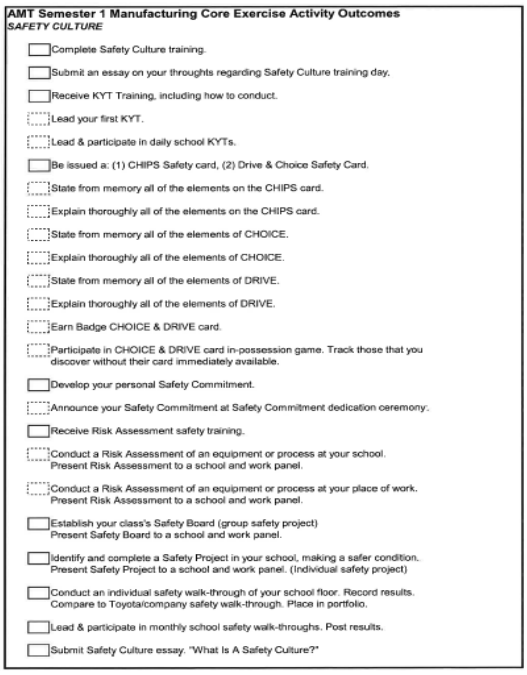
Besides academic curriculum, the students also have to conduct Manufacturing Core Exercises (MCE) weekly. MCE are activities which teach core practices of world-class manufacturing including safety culture, workplace organization, lean manufacturing, problem-solving and maintenance reliability. Each topic will be covered for each semester in length. Figure 6 shows an example of MCE activity outcomes for safety culture for semester 1.

Develop the future worker daily

Not only advanced manufacturing technologies are taught daily, but also soft skills are introduced to the students any time by assigned faculty members or senior employees from Toyota when they are at school or on the floor. Topics included but not limit to the following:

- Attendance culture (school and company)
- Professionalism (school and company)
- Verbal communication
- Written communication
- Interpersonal skills
- Initiative and creativity
- Non-technical work capability (safety/workplace organization/lean operation/problem solving)

- Maturity



AMT Semester 1 Manufacturing Core Exercise Activity Outcomes
SAFETY CULTURE

- ☐ Complete Safety Culture training.
- ☐ Submit an essay on your throughts regarding Safety Culture training day.
- ☐ Receive KYT Training, including how to conduct.
- ☐ Lead your first KYT.
- ☐ Lead & participate in daily school KYTs.
- ☐ Be issued a: (1) CHIPS Safety card, (2) Drive & Choice Safety Card.
- ☐ State from memory all of the elements on the CHIPS card.
- ☐ Explain thoroughly all of the elements on the CHIPS card.
- ☐ State from memory all of the elements of CHOICE.
- ☐ Explain thoroughly all of the elements of CHOICE.
- ☐ State from memory all of the elements of DRIVE.
- ☐ Explain thoroughly all of the elements of DRIVE.
- ☐ Earn Badge CHOICE & DRIVE card.
- ☐ Participate in CHOICE & DRIVE card in-possession game. Track those that you discover without their card immediately available.
- ☐ Develop your personal Safety Commitment.
- ☐ Announce your Safety Commitment at Safety Commitment dedication ceremony.
- ☐ Receive Risk Assessment safety training.
- ☐ Conduct a Risk Assessment of an equipment or process at your school. Present Risk Assessment to a school and work panel.
- ☐ Conduct a Risk Assessment of an equipment or process at your place of work. Present Risk Assessment to a school and work panel.
- ☐ Establish your class's Safety Board (group safety project) Present Safety Board to a school and work panel.
- ☐ Identify and complete a Safety Project in your school, making a safer condition. Present Safety Project to a school and work panel. (Individual safety project)
- ☐ Conduct an individual safety walk-through of your school floor. Record results. Compare to Toyota/company safety walk-through. Place in portfolio.
- ☐ Lead & participate in monthly school safety walk-throughs. Post results.
- ☐ Submit Safety Culture essay. "What Is A Safety Culture?"

Figure 6. MCE activity outcomes for safety culture for semester 1

Integrate into company development

With the integration of the industry to the development of new manufacturing education model, students can get not only most valuable experience and skill development, but also the early involvement with the company culture, structure, leadership and development. When the student is on the floor, she/he is assigned to a designated department and area in which she/he will have the opportunity to be hired for that specific department. During the first five semesters, the students are learning theoretical knowledge in multiple skills in the classroom and being able to relate these theories into real world examples in a manufacturing environment. Each semester floor exercise correlates to curriculum in the classroom. Once the student completes their degree plan the internship phase follows the departmental training plan of specific equipment responsibility and task based training for covering the area in full automatic operations. These tasks must be mastered before the student becomes certified in a production area. Now on the date of hire the student is a viable contributing member of the team, as shown in Figure 7.

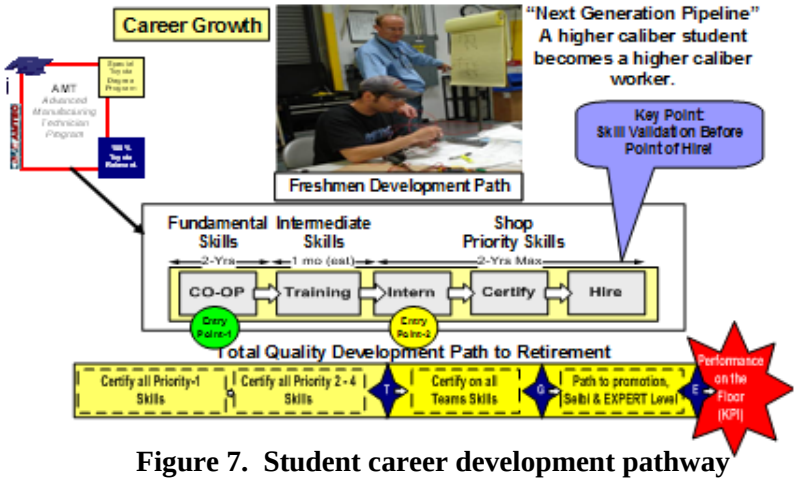


Figure 7. Student career development pathway

Activity Highlights

As we discussed earlier, in addition to working on their daily academic schedules, students also work three days on the floor at Toyota to get the first-hand experience. This experience reiterates the theories taught in the classroom and brings up many class discussions on subject matter allowing a big picture view of the course work. For example Figure 8(a) illustrates student activities in learning fluid power principles through a classroom lab exercise. Figure 8(b) shows how to identify fluid power components with similar hands on exercises on industrial fluid power equipment on the production floor, which can definitely help to reiterate the understanding of the theories in the classroom.

Figure 8 (a). Student classroom activity

Figure 8 (b). Student production floor activity

Performance Assessment

This program was first implemented in Fall 2013. A work-in-progress performance assessment is currently one of our focus. Briefly, students are assessed on a weekly basis allowing them to

receive feedback on their progress. The floor supervisors at the manufacturing facility, assigns a mentor to the individual student and follows company Key Point Indicators (KPI) on progress being made (Figure 9(b)). The KPIs for Toyota are as follows: safety, quality, productivity, and human resources development. The same KPIs are used in the classroom for assessing student classroom performance (Figure 9(a)). The evaluations are rated from scores 1 through 5 making feedback quantifiable. Although Grades are the ultimate indicator, the development of the complete student is the goal. These assessments allow for early intervention into a student having issues with subject matter or any other issue pertaining to their success in the classroom and on the production line.

Advanced Manufacturing Technician (AMT) Evaluation — Toyota Motor Manufacturing

Name: — Employee #: — Evaluation #:

SCHOOL KEYS

Ratings

5 - **Exceptional:** Consistently exceeds performance expectations with virtually no detected errors. Makes significant contributions well beyond normal student responsibilities. Individual requires little direction or oversight.

4 - **Exceeds:** Exceeds performance expectations on a consistent basis. Makes a valuable contribution. Errors are infrequent and are typically detected and corrected by the individual.

3 - **Average/Expected:** Consistently meets but does not exceed performance expectations. Fully competent and is satisfactorily performing both academically and in personal student development.

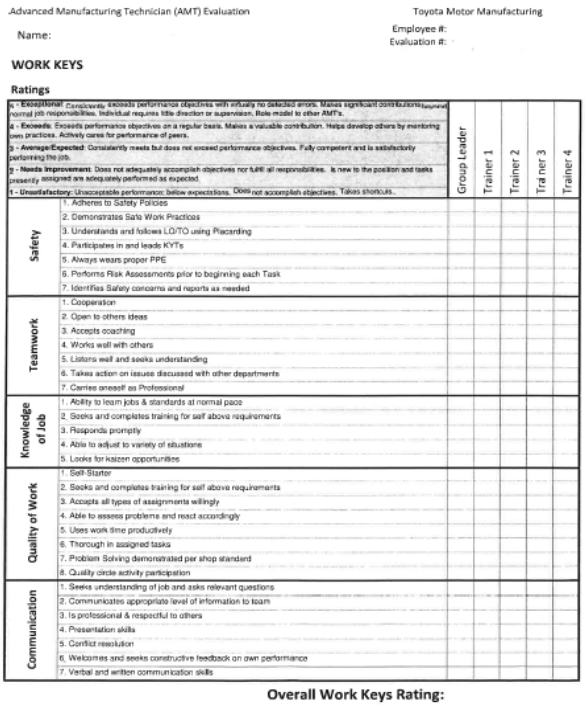
2 - **Needs Improvement:** Does not adequately accomplish objectives nor fulfill all responsibilities; must improve performance within a designated time period.

1 - **Unsatisfactory:** Unacceptable performance and/or student behavior; below expectations. Does not accomplish objectives.

	Project Leader	Instructor 1	Instructor 2	Instructor 3	Instructor 4
Safety: Works safely. Wears proper PPE. Follows all safety guidelines. Watches out for others. Improves safety.					
Attendance: Always on time for class and scheduled activities, returning from breaks, staying the fully scheduled time, etc. Minimizes adjustments to schedule. Exceptions to 100% on-time performance are pre-arranged and pre-approved.					
Quality of Work: All work, both text and project is accurate, neat, thorough, and complete.					
Initiative: Consistently starts tasks and work on time without direction to start. Anticipates needed action. Acts on decisions. Contributes to team initiative.					
Verbal Communication: Presents professional posture and appearance. Speaks so all can hear. Makes eye contact with all. Speaks clearly, concisely, to the topic. Uses effective hand gestures.					
Written Communication: Uses correct grammar and spelling. Well organized. Message is clear. Others can readily read , understand, and act if necessary.					
Homework: All homework submitted. Consistently submitted on-time.					
Diligence & Dependability: Completes all work started. Meets commitments, formal and informal. Ensures group responsibilities (5S, etc.) are consistently met and complete.					
Interpersonal Skills: Works well with others. Resolves conflicts effectively. Respectful of others opinions and boundaries. Respectful to teachers and leaders. Easily accepts and embraces constructive feedback (not defensive).					
Teamwork: Always ready to participate in a team. Fulfills obligations/commitments to team effort. Promotes positive team relations, helps to resolve team conflicts. Never creates team conflicts. Promotes participation of others in team, does not dominate team activity. Recognizes work/accomplishments of others in team. Places team accomplishment/ recognition over own recognition.					
Adaptability: Accepts change without complaint. Participates in actions needed for change. Helps to implement change and achieve new goal. Recommends improvements to better adapt to and achieve change.					
Decision Making: Uses fact-based judgments to make decisions. Makes decisions promptly.					
Professional Appearance: Always clean. Always well groomed. Clothing is always clean and neatly worn. Shirttails tucked, belts worn, when appropriate to clothing. Creates a very positive visual impression of a representative for the school and of the sponsoring company.					

Overall School Keys Rating:

Figure 9 (a). School Key Point Indicators



Advanced Manufacturing Technician (AMT) Evaluation — Toyota Motor Manufacturing

Name: — Employee #: — Evaluation #:

WORK KEYS

Ratings

5 - **Exceptional:** Consistently exceeds performance objectives with virtually no detected errors. Makes significant contributions beyond normal job responsibilities. Individual requires little direction or supervision. Role model to other AMTs.

4 - **Exceeds:** Exceeds performance objectives on a regular basis. Makes a valuable contribution. Helps develop others by mentoring own practices. Actively cares for performance of peers.

3 - **Average/Expected:** Consistently meets but does not exceed performance objectives. Fully competent and is satisfactorily performing the job.

2 - **Needs Improvement:** Does not adequately accomplish objectives nor fulfill all responsibilities. Is new to the position and tasks presently assigned are adequately performed as expected.

1 - **Unsatisfactory:** Unacceptable performance; below expectations. Does not accomplish objectives. Takes shortcuts.

		Group Leader	Trainer 1	Trainer 2	Tra ner 3	Trainer 4
Safety	1. Adheres to Safety Policies					
	2. Demonstrates Safe Work Practices					
	3. Understands and follows LO/TO using Placarding					
	4. Participates in and leads KYTs					
	5. Always wears proper PPE					
	6. Performs Risk Assessments prior to beginning each Task					
	7. Identifies Safety concerns and reports as needed					
Teamwork	1. Cooperation					
	2. Open to others ideas					
	3. Accepts coaching					
	4. Works well with others					
	5. Listens well and seeks understanding					
	6. Takes action on issues discussed with other departments					
	7. Carries oneself as Professional					
Knowledge of Job	1. Ability to learn jobs & standards at normal pace					
	2. Seeks and completes training for self above requirements					
	3. Responds promptly					
	4. Able to adjust to variety of situations					
	5. Looks for kaizen opportunities					
Quality of Work	1. Self-Starter					
	2. Seeks and completes training for self above requirements					
	3. Accepts all types of assignments willingly					
	4. Able to assess problems and react accordingly					
	5. Uses work time productively					
	6. Thorough in assigned tasks					
	7. Problem Solving demonstrated per shop standard					
	8. Quality circle activity participation					
Communication	1. Seeks understanding of job and asks relevant questions					
	2. Communicates appropriate level of information to team					
	3. Is professional & respectful to others					
	4. Presentation skills					
	5. Conflict resolution					
	6. Welcomes and seeks constructive feedback on own performance					
	7. Verbal and written communication skills					

Overall Work Keys Rating:

Figure 9 (b). Company Key point indicator

Rewards for AMT program

This dual work/study program rewards the student by broadening their education and reinforces the academic learning. Students have an opportunity to learn "*lean*" manufacturing principles and develop productive work behaviors that provide excellent self-development skills that are very attractive to employers. The course work implements the multidisciplinary, multi-skilled model with courses in electricity, fluid power, mechanical, fabrication, troubleshooting, and problem solving.

The Toyota AMT program will additionally benefit our youth by preparing them with the knowledge and skills needed for great careers in manufacturing that pays very well. This provides on more additional pathway for young adults who graduate from high school, and

hopefully guides those students towards another high-paying jobs. This is a win –win for the future of San Antonio economically by providing a highly skilled maintenance pipeline to San Antonio's workforce.

For the manufacturing community, this program will accelerant the student to be *fully job ready* for a multi-skilled maintenance position at the end of the two year program; the dual/work study program, prepares the graduate to work on highly technical manufacturing equipment such as robotics, pneumatic/ hydraulic systems, conveyor & transfer systems, electro-mechanical components and programmable logic controls.

Greatest reward and message that will be taken from this partnership with Alamo Colleges and Toyota Motor Manufacturing, Texas is city of San Antonio, Alamo Colleges and its business leaders have faith and confidence in our youth to excel in programs like AMT, and this will champion the future educational and financial success of our community.

Acknowledgements

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