Board 94: Enhancing Teacher Knowledge and Skills in Modern Manufacturing

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Director of Spark! PK-12 Engineering Education Outreach with Texas A&M University Engineering. Her team strives to ignite and foster an engineering spirit from pre-kindergarten through the 12th grade. Dedicated to harnessing the educational power of the maker movement, Spark! was awarded a mobile makerspace from Andeavor, and strives to empower the PK-12 educator by offering professional development through its Maker U program. Spark! is also the new home of the State Science and Engineering Fair of Texas hosting 4,000 6th-12th grade students.

Prior to Texas A&M, she was a Master Teacher in Spring Branch Independent School District for 26 years and a Department Chair for Memorial High School in Houston, Texas. Always interested in unleashing the imagination of students, she was one of the first to incorporate 3D printing in her classroom in Texas and was awarded the PTA District School Bell Award for her service in STEM Education.

She has been a leader in engineering education in the state of Texas throughout her career. Projects include creating and leading new teacher boot camps, developing the Texas standards for the Math/Physical Science/Engineering teacher certification and most recently developing the Texas Essential Knowledge and Skills frameworks in STEM education. Widely known for her work with Project Lead The Way (PLTW), she served as the State Lead Master Teacher training over 700 teachers in PLTW Core Training Institutes for 15 years.

Shelly holds a B.S. degree in Industrial Design and Development and an M.Ed. in Teacher Leadership. She believes in empowering teachers, who then empower students to go out and change our world.

Enhancing Teacher Knowledge and Skills in Modern Manufacturing

Abstract

This Research Experiences for Teachers (RET) program enhances the knowledge and skill-level of middle and high school teachers in both traditional and advanced manufacturing, specifically in manufacturing processes, materials, and metrology techniques.

Twelve teachers were hosted at Texas A&M University (TAMU) for 6 weeks in summer 2018. The targeted school districts were those near TAMU, or with a large number of under-represented students. Among the 12 participants (ten in-service teachers and two pre-service teachers), 11 were from under-represented groups (92%), and five were female (42%). During the training period, the teachers took part in capsulated technical sessions (metrology, conventional machining, computer aided drafting/machining, and additive manufacturing), complementary lab practice, field tours, research seminars, and guided research projects. The deliverables from the program included an implementation lesson/lab plan, as well as dissemination of newly acquired knowledge at an annual teacher summit. The participants also summarized their studies and shared their posters with other research students, teachers from different RET, and REU programs on campus.

The expected outcomes of this program will be the transferring of acquired practical knowledge and skills to excite, empower, and educate students through new class/lab activities; this will enable and inspire students to effectively participate in science/engineering projects as well as to pursue manufacturing careers. Nine out of ten in-service teachers have agreed and in the process of implementing new knowledge and activities into their curriculums.

I. Introduction

The state of Texas enjoys its manufacturing output of $232.2 billions or 15.2% gross state product in 2014, yet Texas has only 7.6% of its workforce in manufacturing [www.nam.org]. However, advanced manufacturing development is facing serious issues due to lack of student interest. Figure 1 shows the demographics of selected independent school districts (ISD) in Texas. The ISDs of Bryan, Navasota, Brenham, and Pharr-San Juan-Alamo (PSJA) have about two times more African American or Hispanic students than the average ISD in Texas. The number of students from low-income families is also 20-50% more than the state average. The dropout rates at Bryan and Aldine ISDs are also particularly alarming (Figures 1-2).

School programs with hands-on and manufacturing focuses – as compared to academic mathematics or pure science-- would be attractive to students since they can relate the training to everyday examples, potential employment, and even advanced careers. Some middle/high schools, however, limit the growth of their technology, robotics, or SkillsUSA programs due to budget constraints and/or lack of technical expertise of teachers. It would be necessary to reverse the trend by providing infrastructure and manufacturing expertise to teachers so that young students are inspired to join technology programs and consider technology or engineering as their primary choice.

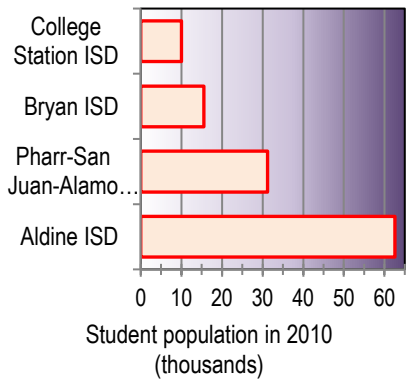

Figure 1: Student population at targeted Texas ISDs [www.texastribune.org].

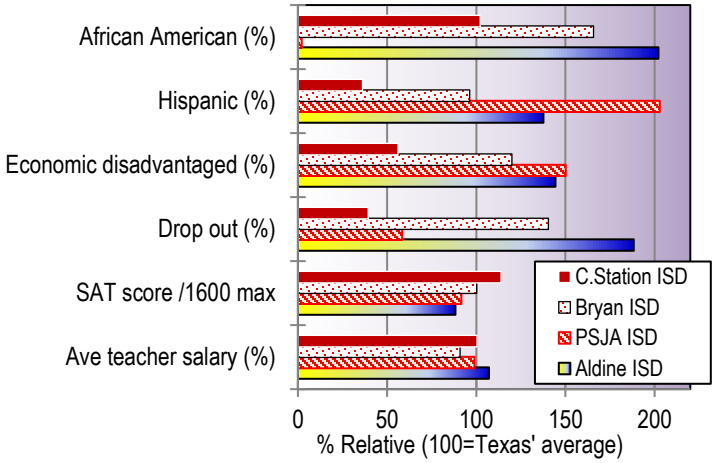

Figure 2: Demographics of targeted ISDs [www.texastribune.org].

This RET Site provides manufacturing experiences to teachers from middle and high schools with large numbers students from underrepresented groups and averaged academic achievement. The program objectives are to:

a) Enhance the teachers' professional knowledge by providing unique research experiences in modern and advanced manufacturing,
b) Use a design thinking approach to help teachers integrating new research knowledge into their class/laboratory activities while motivating young students to pursue engineering careers,
c) Support the school infrastructure for long term partnership, and
d) Enhance the schools' quality and performance.

This paper presents (i) the program structure and preliminary results for our first batch in summer 2018, and (ii) the revised and enhanced program for the second batch of summer 2019.

II. Program Details

This three-year program would involve a total of 36 teachers and focus on three main aspects of manufacturing: metrology, materials, and fabricating processes. The six-week summer research program comprises of an orientation and informative discussion on laboratory safety, research methodology, team brainstorming and objective setting, hands-on research activities with graduate students, seminars, and facility tours to different departments and research centers. Such program would strengthen collegial relationship, enhance the participants' professional knowledge so they could integrate new and appropriate material into secondary school curriculum, and implement the gained knowledge into their classroom and/or laboratory activities. The targeted ISDs are either with high needs in rural areas, or serving a significant number of students from underrepresented groups. Pre- and post-program surveys gage the gained knowledge of the participating teachers while formative and summative interviews by a qualified external evaluator confirm if the objectives are met.

A pair of teachers will work closely with a RET faculty member and his/her graduate students on a specific research project for six weeks in summer. An orientation to review safety,

research methodology, ethics, and be familiar with research facilities will smooth the transition of participants to the program. A preprogram meeting, as suggested by a previous RET Supplement participants, allows selected participants to meet their research team before the program start date. This provides an opportunity for them to meet the research team to clarify the research objectives and scope so that the participants could (i) do preliminary investigation and be well prepared before joining the program and (ii) possibly bring complementary materials from their schools to complement the project. The PK-12 Engineering Education Outreach Office also provides logistic helps with parking permit, renting university accommodation for the summer. Pre- and post-program surveys by this Outreach Office will be integrated in the program. In addition to working closely with graduate students and RET faculty team on a specific research project, all teachers in this program will meet teachers from other on-campus programs for seminar, and/or tour of facilities at different departments. This provides opportunities for cross communication and interaction among all mentors and participants.

Design thinking and team-approach would be applied in research training to foster collegial relationship. A RET faculty member would present a technical issue for the group to brainstorm to come up with goals and optimal approach. The teachers then select materials, learn to use metrology and fabricating machines before collecting and analyzing data. Results are shown to the RET faculty team in a group discussion on how the objectives are met.
All teachers will spend five weeks working on a specific project and spend the last week to integrate research experiences into his/her laboratory or classroom activities with help from Outreach officers. One or two teachers – one in-service and one pre-service teacher -- would be selected to present his/her research work at the annual STEM-4-Innovation Conference hosted by TAMU in College Station in February. They will share their experiences and research outcomes with other teachers from other states attending the conference.

Table 1: Proposed projects.

Project #	**Projects**
1	Traditional manufacturing (2 weeks)
2	Advanced manufacturing (1 week)
3	Material-manufacturing relationship (1 week)
4	Surface engineering (1 week)

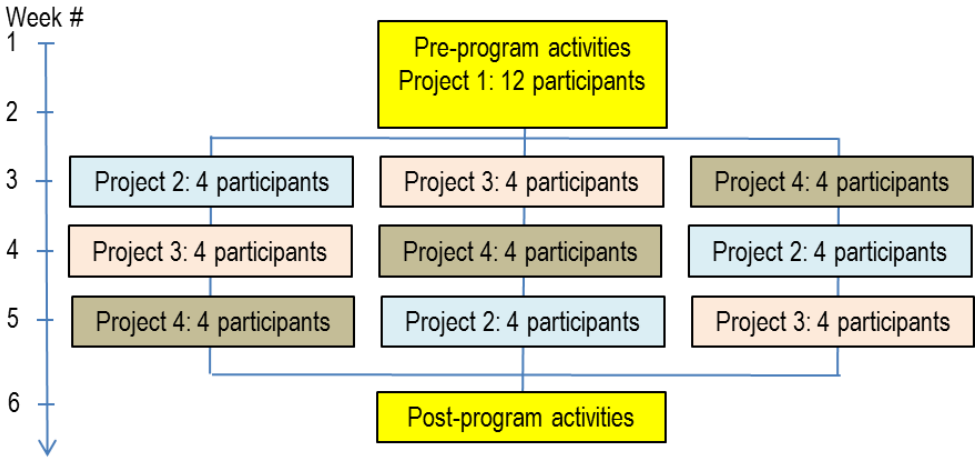

Figure 3: Program structure and timeline.

Table 1 and Figure 3 show research topics that the participants worked on. The teachers started with traditional manufacturing (Project 1) for two weeks since this is the fundamentals that will need to implement in their schools. Groups of two teachers worked on different machine and then rotated through machines to cover all aspects of manufacturing: metrology, material, and fabrication using manual machines before practicing on computer-controlled machines. The teachers then worked in groups of four to complete three other projects (Projects 2-4) in the next three weeks. All projects were listed on the program website with more details such as objectives, expected outcomes, and contact information of TAMU mentors. These topics are relevant to participants who teach technology or mentor students in robotics, SkillsUSA, machine shop, design, computer-aided graphics, or computer aided design toward the required endorsement according to Texas Essential Knowledge & Skills (TEKS) and Texas Science, Technology, Engineering, and Mathematics (T-STEM) initiatives.

Project #1: Traditional Manufacturing.

- Participants: 12 teachers
- Focus: material, metrology, and traditional processes
- Lab Training: Traditional machining uses a hard cutting tool to remove softer materials as chips. A part must be clamped rigidly to withstand a high cutting force while minimize vibration. Participants will learn the safety rules, basic metrology, machining principles, then practice with manual saw, mill, drill, lathe, and grinder to produce and assemble a set of parts within tolerances. In the second week, the participants will be introduced to computer aided drafting (CAD) and computer aided manufacturing (CAM). The teachers will learn using Fusion360 software that will be complimentary to their schools. They will design the same pen and pen-base set using the CAD module, then generate the corresponding CAM codes to fabricate the pen and pen-base set again using computer numerical controlled (CNC) lathe and milling machines.
- Authentic research experience**:** Participating teachers will gain basic manufacturing skills before completing advanced manufacturing projects.
- Equipment: Fabrication: manual lathe, saw, drill, mill, CNC lathe, CNC mill, computer-integrated manufacturing facility. Metrology: caliper, micrometer, height gage, go/no-go gage, measuring microscope, surface profilometer, optical profile projector.
- Schedule and activities: One week with manual machines, and one week with CNC machines. A pair of teachers will work on one machine/task then rotate to others. The faculty mentors will spend one hour/day with the participants, and six students will work with six teacher pairs to finish the tasks.
- Expected outcomes: Experience with metrology techniques using basic hand tools and sorting technique. Know the safety rules in machining laboratory, and principle of machining operations. Obtain hands-on experience with manual and automatic machines. Know the effect of machining parameters on part quality and processing rates to guide their students at home institution to choose appropriate materials and optimal machining parameters.

Project #2: Advanced Manufacturing.

- Participants: 4 teachers
- Focus: additive manufacturing
- Lab training: Conventional manufacturing is suitable for a large part with relatively simple geometry, otherwise advanced manufacturing should be considered. This project allows participants to have hands-on experiences when exploring 3D printing using both plastics and metals. Contact and non-contact metrology techniques are used to qualitatively and quantitatively assess the quality of a machined component.
- Authentic research experience: Teachers would understand the principles and help to collect data for the graduate student assistant who is working on 3D printed metals.
- Equipment: 3D printers for plastics and metals. Metrology: optical measuring microscope, profilometer, digital microscope with 3D measurement.
- Schedule and activities: One week. Teachers will use Fusion 360 learned in Project 1 to custom design a penholder that can be integrated with the machined aluminum pen-base. They will create a STL file and print the plastic samples. The faculty mentor will spend 1.5 hours/day with the participants; a student assistant will work with the teachers to complete the task.
- Expected outcomes: Understand different additive manufacturing processes, materials and limitations. Hands-on experience with designing and printing a functional component.

Project #3: Material-manufacturing relationship.

- Participants: 4 teachers
- Focus: Selection of materials and process parameters.
- Lab training: A wide a variety of metal alloys and polymers are used in manufacturing based on the design and material behaviors. The surface/dimensional quality for a selected material is vastly affected by the process parameters. For example, material with high tensile strength and hardness requires lower machining parameters such as cutting speed and feed rate to avoid thermal damage and tool failure. Machining of polymer requires temperature control to avoid residual stress and distortion. This project aims to provide fundamental understanding on the relationship between material properties and machining setups.
- Authentic research experience: Teachers would understand the principles and help to collect data for the graduate student assistant who is working on minimum quantity lubrication research project.
- Equipment: Fabrication: CNC milling machine, force dynamometer. Metrology: profilometer, digital microscope with 3D measurement. Characterization: tensile and hardness testers.
- Schedule and activities: One week. A pair of teachers will work on one machine/task then rotate to others. The faculty mentor will spend one hour/day with the participants; two students will work with two teacher pairs to complete each task.
- Expected outcomes: Know and practice safety rules. Know common metallic and non-metallic materials. Be able to select proper parameters based on material selection. Teachers can then guide and explain to their students on how to (i) select a material for their projects, and then (ii) choose appropriate machining parameters (e.g. rotating speed of a drill) to fabricate a component for their school project.

Project #4: Surface engineering.

- Participants: 4 teachers
- Focus: Surface finish, imaging technique, surface characterization.
- Lab Training: Performance of a machined part or its cosmetic appearance depends on how the final layer of materials is removed. The surface finish of complete part can be characterize and measure using different techniques. In addition to surface imaging, advanced technique can be used to provide image of the machined surface in great resolution, and even can identify the elements and their composition of a material.
- Authentic research experience: Teachers would understand the principles and help to collect data for the graduate student assistant who studies the built-up-edge formation on microcutting tools.
- Equipment: Profilometer, interferometer, scanning electron microscope (SEM).
- Schedule and activities: One week. A pair of teachers will work on one machine/task then rotate to others. The faculty mentor will spend one hour/day with the participants; two students will work with two teacher pairs to complete each task.
- Expected outcomes: Understand surface finish and gain hands-on experiences with contact and non-contact surface roughness measurement. Expose to advanced imaging and energy dispersive X-ray analysis using SEM. Although it is unlikely that a secondary school would have these advanced systems, the teachers can describe what each system can do to encourage their students going to university after graduation.

III. Participant Selection

Table 2 lists the targeted independent school districts with great potential for success. The targeted institutions offer pre-engineering, technology, and science programs that are closely related to the research focus of this proposal. The Bryan ISD and Aldine ISD are serving a large number of African American and Latino students in their school districts.

Table 2: List of targeted school districts.

Independent school district (ISD)	Website	Location in Texas	Note
College Station ISD	www.csisd.org	College Station	Near TAMU
Bryan ISD	www.bryanisd.org	Bryan	Near TAMU, high African American population
Aldine ISD	www.aldineisd.org	Houston	High African American population
Pharr/San Juan/Alamo ISD	www.psjaisd.us	Pharr	High Hispanic American population

IV. Follow-up Plan

The Outreach Office and RET faculty team worked with participating teachers especially during the first and last weeks of the summer program to come up with a sustainable follow up plan. Raise Achievement LLC, the external evaluator, collaborated with the Outreach Office to assess the following steps:

a) Implementing plan. A pair of teacher from the same school completes an assignment that describes the gained knowledge and how to implement it to classroom lessons or projects. The pre-service teachers may join the in-service teacher in this planning stage. After having a specific plan, the team identifies issues such as lack of resources and proposes how to use the $1,600/teacher toward implementation.

b) Sharing facilities. The team comes up with plan to bring students back to TAMU for engineering lab tours, workshops, and possibly share facilities at TAMU to complement school assignments or competition projects. Such work is supported by the graduate students who work with the teachers during the summer research program.

c) Developing long-term relationship. Meetings for following academic year among RET project team members, teachers, school district officers, and industry representatives are planned to assess the success of implementing plan, its schedule, impact on students and parents, and to generate ideas for broader impact.

d) Sharing experiences. Two teachers (one in-service and one pre-service teacher) are invited to participate and present their research experiences at the annual STEM-4-Innovation Conference in Texas. The in-service teachers also present how they integrate new knowledge gained from the research experience into their lessons, laboratory or school projects and the impact on students.

V. Preliminary Results

Manufacturing focused training for the first batch of twelve teachers was completed in summer 2018.

- Ten in-service and two pre-service teachers
- Five female (42%)
- Nine African /Latino American (75%)
- All from ISDs with high under-represented groups.

Hands-on laboratory practices using appropriate machines /instruments and complementary theories were provided to the participants. All had two-week leveling training before attended the more focused and relevant topics in a group of four during the next three weeks. The teachers spent the last week to prepare posters and plan for curriculum integration at their schools (Figure 4 a-f). Nine out of ten in-service teachers pledged and have their principals' approval for their proposed curriculum that incorporated what they have learned in this program.

Post program surveys show the participants' satisfaction with the training (Figure 5). The report from program's external evaluator shows participants' feedback and indicates some areas for improvement:

- Plan for group housing to facilitate after-hour collaboration among participants.

- Offer additional hands-on practice with traditional manufacturing processes, more time with metrology exercises, and handouts to help implementation new materials into their curriculum.
- Practice and reiterate the steps in design thinking approach.
- Link or integrate different laboratory exercises and projects.

(a) Hands-on practicing with metrology tools

(b) Using manual machine tools

(c) Fusion 360 training

(d) Poster presentation to other RET participants

(e) A penholder set and 3D printed drill.

(f) Participants with some of faculty advisors

Figure 4. Activities of RET participants in summer 2018.

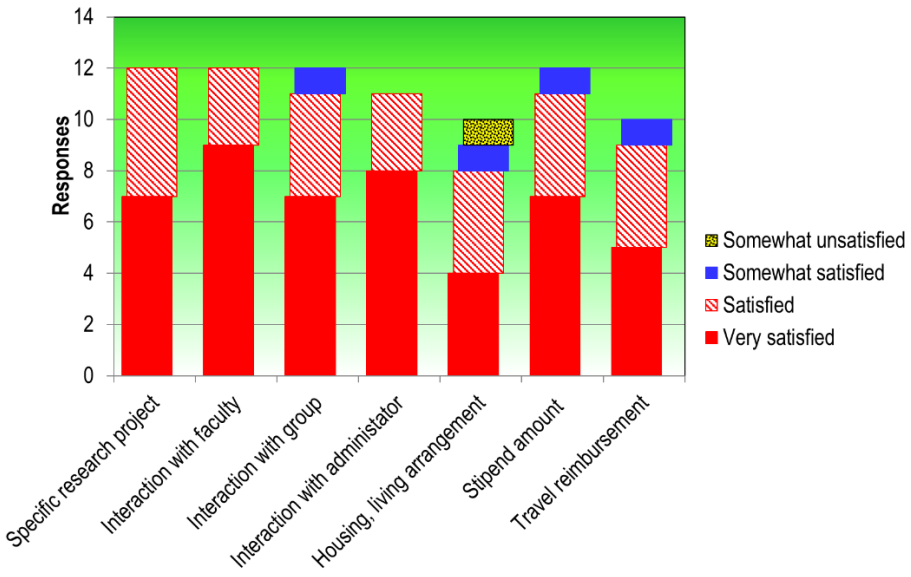

Figure 5. Post program survey result.

VI. Summary and Recommendation

This three-year program improves manufacturing skills of teachers from schools with high numbers of underrepresented groups. The first batch of ten in-service teachers and two pre-service teachers:

- Learned and practiced fundamentals of traditional manufacturing, additive manufacturing, understood the material-manufacturing relationship and the importance of surface quality.
- Nine in-service teachers are implementing new knowledge into their curriculums.

For the coming summer, we plan to streamline and enhance the program by:

- Increasing practice sessions in metrology and traditional manufacturing and help participants to implement new lab exercises.
- Reiterating design approach and link different projects.

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