ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #38101

Smart Manufacturing for Underserved Workforce Development

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Abstract

The digitization of machines, tools, and other elements of manufacturing systems presents substantial benefits, but there is a need to overcome technical and workforce skills gap regarding Smart Manufacturing (SM) technologies and processes, especially for underserved small and medium manufacturers (SMMs). Increasing representation of minority workforce demographics with knowledge of advanced manufacturing technologies is required for effective SM technology adoption and implementation, to sustain regional manufacturing superiority. This effort demonstrates a strategy to create a SM curriculum and certificate program that promotes SM concepts in underserved SMMs and upskilling an underrepresented (Hispanic) workforce, by developing industry-relevant training materials and research laboratory practices. Existing academic, industry, workforce, and economic development partnerships were leveraged to capture and address the diverse learning needs across the entire regional SM pipeline. The key tasks conducted to fulfill the project goals included the development of a SM curriculum and SM focused laboratories at the University of Texas at El Paso (UTEP), approval of the SM certificate program to engage and increase SM knowledge in underserved regional manufacturers, and development of industry relevant use cases in SM related areas. The resulting infrastructure provides an underrepresented workforce demographic with access to a state-of-the-art SM research facility, hands-on experience developing case studies, and interdisciplinary knowledge in SM engineering. The SM framework is expected to increase the number of SM trained minority engineers (estimated 48 Hispanic students), increase industry deployment and adoption through development and implementation of SM specific use cases, and increase the SM supply chain through economic development partnerships. The strategy presented in the paper provides an approach to increase SM adoption in historically underserved communities.

1. Background and Need for Smart Manufacturing Educated Workforce

Smart Manufacturing (SM) technologies and methodologies, offer a strong potential solution to affect product quality improvement, productivity increases, energy use improvements, and safer manufacturing workplaces, through networked information-based technology innovations within the manufacturing system, [1]. There is a widening gap between available and required skilled labor in many advanced manufacturing jobs Rapid technological advancement in industry coupled with a large number of retiring baby boomers. Additionally, manufacturing organizations often neglect the key aspect of hiring, training, and retaining a SM educated workforce able to operate a smart factory even as they spend considerable effort in implementing modern equipment and operations for competitive reasons [1].

SM is the future paradigm for manufacturing and estimated to generate $371 billion in net global value over the next few years by streamlining design and manufacturing processes and managing supply chain risks and providing greater flexibility and control of interconnected manufacturing processes [2]. Currently, many companies are implementing SM technologies and investing in expanding the traditional skill sets of industrial, manufacturing, and systems engineers need to support the interdisciplinary collaboration it mandates [3]. Although, the digitization of machines, tools, and other elements of the manufacturing systems can realize significant benefits for the manufacturing industry, there are significant technical and workforce skills gaps regarding SM technologies and processes, especially for small and medium manufacturers (SMMs) that need to be addressed [4]. In early 2000, Germany implemented extensive worker training as part of their mitigation strategy when faced a similar position as that of the US, with the risk of a shrinking manufacturing base [5]. A 2017 McKinsey study listed

ramping up workforce development efforts and making long-term investments to upgrade manufacturing plants and equipment for digital readiness, as key priorities that need to be addressed [5]. Researchers in Canada, conducted a study to understand future Industry 4.0 education needs by understanding students' views on the use of SM technology to develop the skills and competencies of future students to match SM needs [6]. Governments of countries such as South Korea, Taiwan, and Singapore, all key players in the Asian manufacturing market, are also pursuing SM technologies and researchers are currently developing maturity models for SM adoption.

As evident from these initiatives, the need for SM learning infrastructure requires engineering colleges and technical schools to develop new curriculum to better prepare graduates for this new SM environment to support the reconfiguring factories and supply chains [8]. There is a clear need to focus on developing a SM curriculum specifically focused on skill sets and competencies needed for effective SM technology adoption and implementation to address current knowledge gaps and sustain manufacturing superiority. Consequently, there is a clear need for SM skill set, voiced by the proposing team's industry partners where expertise is sought in the SM related areas of digitization of tools, equipment performance, data analytics & adaptive controls, real-time process engineering, automated qualification of products, and robotics and flexible automation, for sustaining their competiveness.

To support the next generation manufacturing workforce in the digital era, this effort was aimed at developing a comprehensive hands-on SM training and certificate program to be offered at UTEP's College of Engineering's Industrial, Manufacturing and Systems Engineering (IMSE) department in collaboration with Texas Manufacturing Assistance Center (TMAC) Paso del Norte (PdN). The main objectives of the project were to 1) develop a SM curriculum to educate workforce in SM technologies, 2) leverage workforce/economic development partners to maximize innovative deployment platforms and 3) utilize industry collaborations to research and address exemplar use cases using SM technologies in a dedicated SM laboratory. In summary, a regional industry, government, and academia partnership was realized for addressing the competency based needs to attract and grow a next generation, SM educated workforce, particularly across underrepresented groups (Hispanic), resulting in a technical workforce with the necessary skill set to implement SM.

2. Methodology and Technical Approach for Smart Manufacturing Curriculum Development

By leveraging existing regional academic, industry, and workforce development partnerships a comprehensive education and workforce development plan was developed to address the diverse learning needs across the entire potential SM pipeline. The following education and workforce development SM specific challenges were evaluated in the development of the SM curriculum:

1) Effective delivery of industry-based SM best practices, capabilities, and programs
2) Expand opportunities for continuous learning through customized hands-on training, project-based learning, and industry recognized SM certifications
3) Updating traditional curricular to integrate SM design, innovation, and operations
4) Promote innovative learning strategies and creative problem-solving skills using SM
5) Actively promote and identify opportunities to diversify within the regional workforce (Veterans – Ft. Bliss, Women, and Underrepresented Minorities-Hispanic).

The key enablers for overcoming the technical challenges listed are listed below:

- Drive towards industry-driven curriculum with hands-on experiences incorporating SM

- Partner with Workforce Solutions Borderplex for workforce development at educational levels
- Leverage MEP network through active participation in TMAC's SM Center of Excellence
- Engage local industry leaders in optimizing manufacturing processes using SM methodologies
- Experience with previous, successful EWD specific certificate programs

3. Structure of the SM Curriculum

Any education and workforce development (EWD) plan needs to leverage existing strong relationships among key stakeholders and requires experience in establishing and implementing successful EWD programs. Implementing best practices from previously established programs ensures alignment of EWD needs to efficient technology innovations across the SM sector as per associated regional industries (e.g. bio-medical, automotive, commercial electronics, etc.). The participating students are expected to be knowledgeable in SM related technologies and methodologies and be able to identify SM opportunities in their workplaces. Figure 1 provides an overview of the strategic approach required to upskill incumbent workforce in SM specific technical concepts.

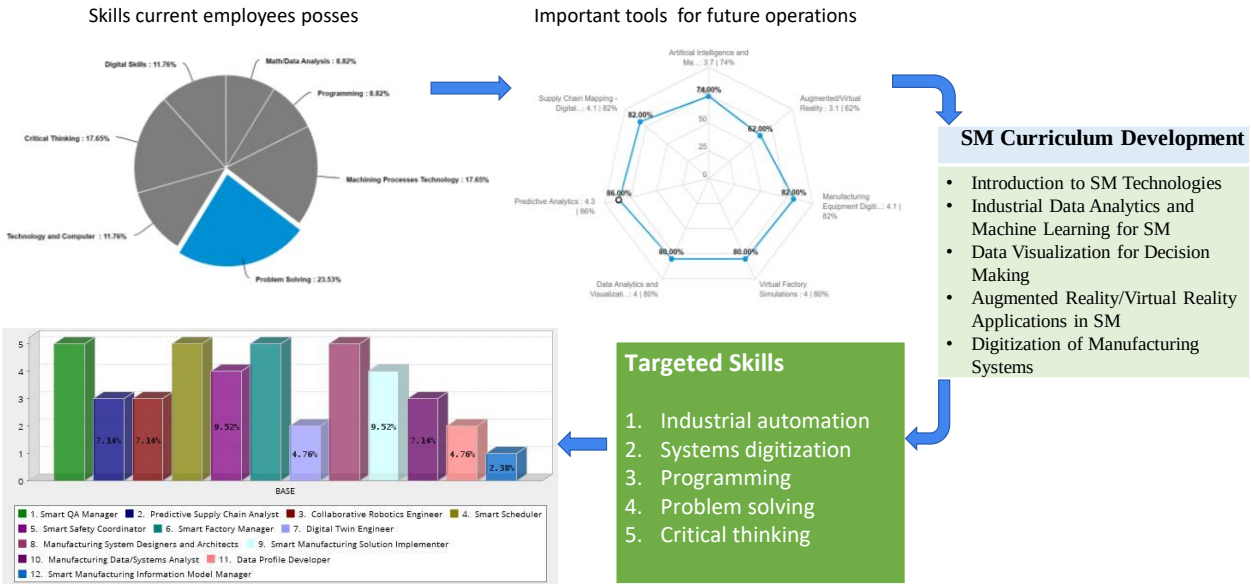

Figure 1. Smart Manufacturing Education and Workforce Development Strategy

At the start of the SM curriculum development, it was important to understand the current skills of the regional manufacturing workforce and gather perspective on the future tools and skills needed in the drive towards SM adoption and a survey was sent to regional manufacturers, workforce development, and economic development partners. The survey highlighted that current workers were proficient in problem solving and machining processes technology. Furthermore the need to acquire advanced knowledge in predictive analytics and enabling industrial internet of things by equipment digitization were listed as future needs. This knowledge guided the investments in SM specific laboratory infrastructure, development of SM focused course modules, and researching SM relevant use cases for industry deployment. The end goal was to effectively provide the targeted SM skills to fulfill future job requirements in an Industry 4.0 manufacturing environment.

3.1. Smart Manufacturing Curriculum Development

The best practices from the two previously deployed certificate programs were leveraged to develop a comprehensive industry driven/recognized SM curriculum. Currently not many institutions provide SM specific expertise and a SM curriculum provided by a Hispanic serving institution (HSI) such as UTEP can greatly benefit the regional workforce to acquire SM related skills and competencies. The program will be promoted as part of fast track programs in the COE, where undergraduate students will be able to take up to nine credit hours as part of their dual UG-MS credit. When students obtain their undergraduate degree they will have three courses from the certificate program, which will count for their SM certificate, and any MS degree offered in the UTEP COE. Overall, about 60 students are expected to participate in the program annually and about 48 out of them are expected to be Hispanics.

The newly developed Smart Manufacturing Innovation (SMI) lab was retrofitted with SM related technologies (digitization, automated data acquisition and analysis, remote operations monitoring and quality, universal programmable robot, remote IO link, machine vision system) and APIs (predictive algorithms, dashboard visualizations, mobile tools, equipment sensing, data extraction and storage) for facilitating SM research and development. The Main components of the SM lab are as follows: UR3 – Small Collaborative Robot, Yamaha YK350X SCARA Palletizer Robot, Linear Actuator, Conveyor, Cognex Machine Vision System, and Siemens Programmable Logic Controller. The Internet of Things (Io) setup includes the following software elements: Node Red, Node JS, and IO Link with MQTT Data Transfer Protocols. The IoT also include the following tools and sensors: Raspberry PI, NI cDAQ temperature module, and Type K, thermocouples.

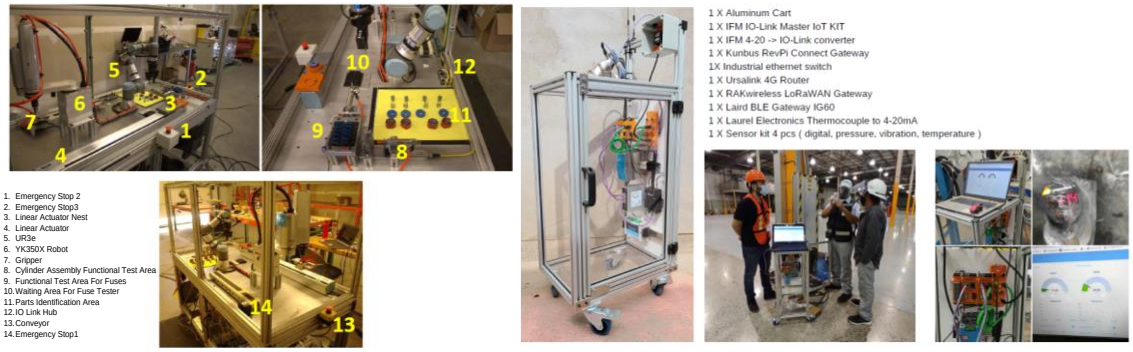

Figure 2. Smart Manufacturing Innovation Laboratory

Five core SM curriculum course modules (1-Introduction to SM technologies; 2-Industrial Data Analytics and Machine Learning for SM; 3-Augmented Reality/Virtual Reality Applications in SM; 4-Data Visualization for Decision Making; 5-Digitization of Manufacturing Systems) were integrated within existing related courses. Each course's structure covers manufacturing and process technologies specific to the individual topic. Three courses were dedicated to advancing knowledge on smart manufacturing and process technologies while the two data science related courses provide knowledge in utilizing data analytics and visualization methods for process optimization and decision making in manufacturing environments. Each course will employ project-based learning (with the objective of challenging students with industry-relevant projects) and mastery learning since these

approaches closely resemble industry conditions and expectations. Having industry relevant projects will ensure that students graduate with industry-desired skill sets and students are familiar with challenges in real world applications. The SM certificate program was approved by the UTEP Graduate Council - Curriculum Committee and will be offered starting with the Summer 2022 semester.

3.2. Regional Deployment of Smart Manufacturing Technologies

Utilizing TMAC's access to local industry, local workforce solution agencies (Workforce Solutions Borderplex), and economic development organizations (Borderplex Alliance), the SM curriculum and certificate course was promoted to the regional workforce. The program is tailored towards industry professionals, looking to expand their skills and expertise in SM to the program, who can start with the certificate program and then potentially transition to obtain a full MS degree.

Five awareness sessions were conducted regionally to promote the SM curriculum and recruit more minority participants and engage regional underserved SMMs, who can greatly benefit from access to SM methodologies. These sessions included brief overview of SM topics and their applicability to various regional manufacturing industries (Figure 3). The bilingual ability of the UTEP SM program faculty was leveraged to achieve broader engagement and acceptance of the SM program in a Hispanic workforce. The registered participants included nine from Industry (representing seven companies), five from Government/Economic development, and two from Education and Workforce Development.

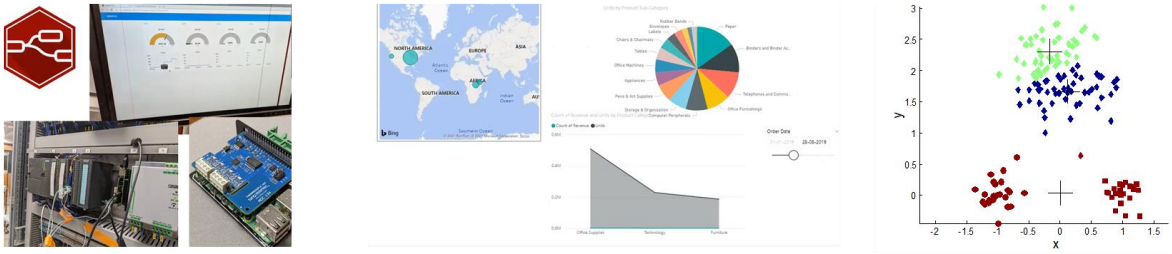

Figure 3. SM Specific Webinars

The local MEP center worked with the local workforce solutions organization that conducts special training and workforce development programs for underserved communities, for increased program outreach through two SM workshops. Nine participants representing five manufacturing companies attended the workshop.

Figure 3. SM Workshops

A SM focused conference was conducted in November 2021 that was attended by ~120 engineering students and ~10 manufacturers consisting of regional industry partners. Participants benefitted from industry experts (representing manufacturing, economic development, workforce development, and SM vendors) discussing how SM specific skills will impact future workforce and technology investments

3.3. Development of Use Cases

Four, industry relevant, use cases were developed within the SMI lab and Keck Center facilities, to promote SM integrated solutions that address specific operational challenges of local underserved SMMs. Some examples of case studies conducted through this project and applicable course module are as follows.

- Manufacturing process monitoring and control (Digitization of manufacturing systems)
- Optimized overall equipment effectiveness (Industrial data analytics)
- Advanced workforce training (AR/VR for product assembly/disassembly)
- Adaptive manufacturing operations dashboard (Data visualization for decision making)

Additionally, industry-relevant training in SM technologies with opportunities for students to receive mentorship from industry collaborators and better prepare them to implement new SM specific technologies for process improvement and optimization. The Borderplex Alliance, an organization dedicated to economic development and policy advocacy in the Paso del Norte region, will guide the deployment strategy for SM adoption and workforce development effort. Industries representing automotive, medical devices, consumer products, electric motors, and electronic components will be engaged to assist with the SM curriculum adoption as well as the integration of real-world projects that can benefit from implementing SM principles.

4. Discussions and Conclusions

To respond to a growing national need in manufacturing, UTEP developed a SM specific curriculum that has the potential to serve and up-skill a minority workforce population with a strong history in manufacturing. The research efforts will provide new knowledge/tools in the SM area and will contribute to the IMSE department's strategic goal to develop our capabilities the SM systems area. This project provides students with a state-of-the-art research facility, hands-on experience and interdisciplinary knowledge in advanced manufacturing, data analytics, and smart manufacturing engineering. The SMI research lab will be able to significantly enhance its capabilities and will be a key part of several existing and future SM knowledge embedded course offerings.

The project addresses the following key stated EWD goals:

- Development of Smart Manufacturing infrastructure
- Increase number of SM trained engineers
- Increase Industry deployment and adoption through hands-on trials at industry partners
- Increase potential SM workforce
- Increase SM supply chain

One unique EWD strategy embedded within the proposed EWD plan will be to implement customized continuous learning opportunities (including credentialing) through public-private partnerships (TMAC PdN and Professional and Public Programs (P3)). Steering committees (focused on SM technology development and implementation) will be established with representation from industry, government, and academia to identify the targeted SM skill sets that will drive continuous curriculum development. The primary outcome of this effort is a future workforce that is knowledgeable in SM related technologies and methodologies to anticipate, identify, and address efficiency opportunities in manufacturing operations and supply chain networks.

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