Innovations in Additive Manufacturing Workforce Development

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Abstract

With the nonstop advancements in Additive Manufacturing (AM), the American workforce needs technical training in several aspects of this leading-edge technology in its utilization and adaptability. The objective of the Additive Manufacturing Workforce Advancement Training Coalition and Hub (AM-WATCH) is to address current gaps in the knowledge base of 21st century professionals through the development of AM-WATCH educational materials tied to ABET Student Outcomes, delivery of professional development activities, and expanded outreach activities targeting K-12 and community college teachers and students. The project significantly enhances and expands the current resources developed by prior National Science Foundation projects (remote AM facilities, AM learning curriculum and educator workshops) to encompass hands-on desktop 3D printer-building modules, AM equipment operation/maintenance guidelines and additional remotely-accessible AM equipment laboratories. The project establishes a number of cutting edge AM innovations and targets to engage students in STEM and other technical careers while teaching them the latest AM trends and technologies. In short, this project brings many unique innovations to AM practices in teaching, learning, and training.

Key words

Additive Manufacturing, STEM, Studio, ABET, Collaboration

Introduction

In the 20th century, high school graduates were able to obtain a decent manufacturing job with a stable income level. However, this kind of job moved offshore, and a different type of manufacturing career perspective took its place today. These new manufacturing jobs require more advanced skill sets than are available at the high school level. The existing gap between worker skill sets and industry needs has resulted in approximately two million vacant manufacturing jobs in the U.S. It is clear that filling these jobs requires new techniques and methodologies for training workers in advanced manufacturing technologies [1].

AM techniques have been providing several advantages to many problems faced by the current manufacturers. Producing a product layer by layer eliminates the waste that results from several conventional processes. AM technologies also greatly reduce the time between designing and fabricating a product. However, mastering them requires specialized workforce training since AM technologies have been advancing continuously.

The education of a skilled AM workforce is critical to the economy of the United States. Over 80% of U.S. manufacturers recently reported an overall shortage of qualified employees. A significant impact could be made on the future workforce if AM could interest 1% of the current 59 million K-12 students in STEM careers. In a report reviewing the findings of an NSF AM Workshop, the authors noted that while numerous companies and institutions have educational resources and training materials, "no readily applicable, proven curriculum model exists for integration of AM education and training into the technical knowledge bases." The appeal of AM to K-12 and community college students will result in the recruitment of a new generation of employees into STEM careers [2-3].

Areas demanding attention include: 1. Educating the general public and K-12 students about the AM industry, 2. Creating a modularized AM curriculum that can be incorporated at the 9-12 and community college levels, 3. Training of the teachers to promote the inclusion in a curriculum, 4. Providing remote access opportunities such as Massive Online Open Courses (MOOCs) and shared AM laboratories, 5. An awareness of AM entrepreneurial opportunities, and 6. Continued refinement of the distributed resources as technology progresses.

This current paper reports the three unique AM-WATCH activities which are currently under development and implementation: 1. A newly developed framework presenting how the resources of the AM labs can be shared remotely, 2. Demonstration of how the Studio Pedagogy can be integrated into AM training, and 3. Understanding and implementation of how AM instruction can be used for the ABET student outcome attainment.

Sharing the AM Resources

A newly developed smartphone application is under beta testing among the AM-WATCH hubs and participating institutions, and can be seen in Figure 1. AM laboratories are currently linked with very precise network cameras. All of the network cameras are equipped with 2-way communication, infrared night vision, an SD card slot, digital zoom (x10), pan & tilt, and motion alerts. They also have two-way audio connection, which is a great feature that lets anybody chat with the laboratory personnel throughout the remote access. These cameras also let the user monitor the part production from start to end, and thus are able to inform the laboratory personnel when there is an issue. They are also very convenient to take snapshots of the production steps and laboratory experiments.

The remote access application for the AM Remote Access Network can easily be downloaded through any smart phone and gives the user an opportunity for the live video footage anywhere with an internet connection, on any mobile device. All cameras have the pan and tilt features for better viewing. The developed system provides around-the-clock observation with night vision capability, which allows the user to see up to 26 feet in complete darkness. Videos of laboratory exercises and snapshots can be recorded to a microSD card up to 32GB. The system also sends an email or push alert to the user's cellular phone when any motion is detected [4].

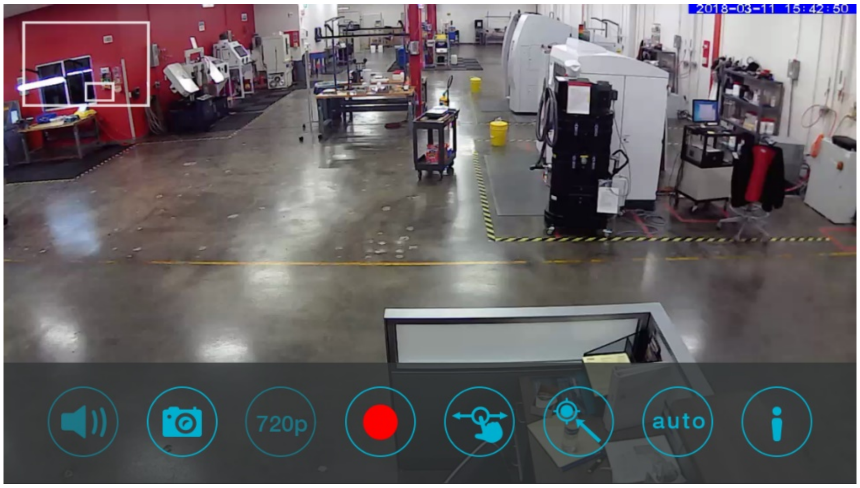

Figure 1: Remote Access Capabilities of the Newly Developed Smart Phone Application for the AM Laboratories

Current practices provide that any student who is taking any AM course or training with a partnering institution can jointly see the works going on in any institution and take an action to make any statement or input to an AM laboratory attendee.

Studio Based AM Training

The AM-WATCH targets to train minimum 30 STEM educators every year with intensive AM workshops. These training programs are delivered in a Studio format so that the STEM teachers learn and implement the concepts at the same time. Studio is an approach to teaching that can be used to replace the standard lecture style. Emphasis is on cooperative and collaborative activities. In newly developed and implemented AM Studios, instructional delivery includes discussions, debates, presentations, case studies, real world exercises, computer projects, work with samples, and various other events.

While Studio attendees learn the latest trends and technologies in AM they also gain valuable skill sets about the various aspects of the AM practices, Accreditation Board for Engineering and Technology (ABET) accreditation, and how to assess and attain student outcomes for their programs' continued improvement and self-study report preparation. Studio exercises and the final evaluation delivered at the end of the event present very good opportunities to gain great experience to learn and exercise such kind of terminologies and practices.

In each project cohort, two studio based hands-on workshops are organized. The main objective of the workshops is to deliver the currently developed MOOC modules and activities to workshop attendees who are coming from several high schools, community colleges, and four-year universities. Attendees also set up their own printer as seen in Figure 2, and run a project in teams of 3-4 members. In addition to many valuable presentations and industry tours, each team presents its accomplishments at the end of the program [5].

Figure 2: Astrit Imeri, a Tennessee Tech University grad student, shows Edmonds Heights K-12 teacher Cathy Webb how to troubleshoot 3D Printer mechanical errors at a two-day Studio Workshop

AM for Measuring the ABET Student Outcome Attainment

Before each team starts working on an entrepreneurial part design and printing project, the foundation of the ABET Criterion 3 (Student Outcomes) and Criterion 4 (Continuous Improvement) is presented to studio attendees. A template presentation is given, and the expected outcomes of the project are detailed. Coaching support is also provided throughout their work on the project.

The ABET Criteria for Accrediting Engineering or Engineering Technology Programs are based upon the knowledge, skills, and behavior that students acquire in a program through the curriculum. The acquired knowledge, skills, and behavior are considered as student outcomes (Criterion 3). Consequently, the program needs to set its own student outcomes to achieve program educational objectives (Criterion 2). The achievement of the program goals and objectives is verified by the assessment and evaluation of Criterion 3. This whole process is considered as Criterion 4 [6].

At the end of each Studio Workshop, an external evaluator conducts an evaluation about attendees' learning and satisfaction about the delivered subject matter and logistics of the Studio. Table 1 provides the outcome of ABET related feedback received from the Knoxville Studio attendees.

Table 1: ABET Student Outcome Attainment of the Knoxville Studio Workshop Attendees (N=15)

ABET Criterion 3: Student Outcomes	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
I have increased ability to design a system, component, or process to meet desired needs.	60.0% (n=9)	13.3% (n=2)	20.0% (n=3)	6.7% (n=1)	0.00%
I have increased ability to function effectively as a member of a technical team.	60.0% (n=9)	26.7% (n=4)	6.7% (n=1)	6.7% (n=1)	0.00%
I have increased ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and use appropriate technical literature.	46.7% (n=7)	40.0% (n=6)	6.7% (n=1)	0.00%	6.67% (n=1)
I have an increased understanding of the need for and ability to engage in self-directed continuing professional development.	66.7% (n=10)	20.0% (n=3)	6.7% (n=1)	6.7% (n=1)	0.00%
I have an increased understanding of and commitment to professional and ethical responsibilities including a respect for diversity.	66.7% (n=10)	13.3% (n=2)	13.3% (n=2)	6.7% (n=1)	0.00%

Through the AM Studios, AM-WATCH teaches STEM educators how to build 3D Printers with confidence to help them prepare for real world AM careers. The project also uses MOOCs to inform audiences of all ages and skill levels about AM trends, safety, innovations, and entrepreneurship.

Conclusions

AM is rapidly changing the design and production of all kinds of products, from those used in daily life to critical parts utilized in advanced technologies. With the increased national and global focus, there is clear evidence of the growing demand for technical experts in AM. AM-WATCH was established to address current gaps in the AM knowledge base of 21st century manufacturing professionals. The students gaining these AM skill sets are more prepared for advanced career placement. The project is establishing several cutting-edge AM innovations in remote laboratory collaboration, studio based hands-on learning and gaining valuable skill sets in ABET Student

Outcome Attainment process. A number of future developments and studios is underway in different parts of the continental US.

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