Offering Hands-on Manufacturing Workshops Through Distance Learning

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Abstract

This paper reports on how institutions collaborating on Additive Manufacturing (AM) and Smart Manufacturing (SM) have been able to adapt to the COVID-19 pandemic and be able to modify their planned activities in 2020 in an effort to continue delivering quality training and education to educators across the country. The pandemic made it impossible to offer the usual on-ground workshops to STEM educators and industrial practitioners. As a workaround, the project teams offered instructional delivery via Zoom and Microsoft Teams while also providing distance learning tools online. The best practices of the delivery and pros/cons of the operations will be presented with the feedback received from the participants.

Introduction

Many countries around the world have successfully adopted strict industrial policies for the last four decades. For instance, the current industrial policy “Made in China 2025” has the main objectives of transforming China to innovation and prioritizing “intelligent systems” [1][2]. As a result, in the year 2010, the United States lost for the first time in modern history its position as the world’s largest manufacturer [3][4]. The small gap between the two countries continues to rapidly widen due to the accelerated growth in the Chinese manufacturing industry, and its rapid transformation to research and innovation, particularly in artificial intelligence.

The fast growth in the Chinese manufacturing and innovation prompted several countries to finally adopt industrial policies to guide and accelerate growth in the manufacturing industries in certain directions [4]. The German “Industrie 4.0” [5] and the French “New Industrial France” [6][7] policies were launched in 2011 and 2013 respectively. Korea launched its industrial strategy named “Manufacturing Innovation 3.0” in 2014 [8] followed by Japan in 2016 with its industrial strategy known as “Society 5.0” [9][10]. By the year 2018, five of historic major “factories of the world,” China, France, Germany, Japan, and Korea, had industrial policies in place. The United States was one of few major industrial powers with no policy in place.

The two projects Smart Manufacturing for America’s Revolutionizing Technological Transformation (SMARTT) and Additive Manufacturing Workforce Advancement Training Coalition and Hub (AM-WATCH) were launched in 2018 and 2016 respectively to answer the need for preparing a workforce that is trained in Smart Manufacturing (SM) technologies.

The spread of the Corona virus that causes COVID-19 resulted in a significant impact on the world, and left many industries paralyzed for months such as the aviation industry or suffering from significant losses such as the automotive industry [11]. As with many other projects, handling the COVID-19 pandemic restrictions was one of the challenges for the project teams. In response to the pandemic, the third smart manufacturing workshop was postponed from the summer to the winter of 2020, and was converted from on-ground to virtual. The time allotted for the hands-on activities was converted to a do-it-yourself day, and resources for the activities were provided in one session and on the project website. The AM-WATCH workshop was also moved to the winter, and into a hybrid workshop in which participants were able to take part in the workshop on-ground or online.

The Scope of the AM-WATCH and SMARTT Projects

Training workers to be skilled in AM and SM is costly and time consuming. There is no AM-focused degree program at the associate and undergraduate levels yet, although some universities offer degrees in AM at the graduate degree level. In response to the needs of AM workforce development of technicians, the AM-WATCH Project provides a number of unique innovations to deliver several knowledge blocks of AM to secondary and post-secondary STEM educators. The goal of the SMARTT project shares the same deliverables in SM field. Tables 1 and 2 highlight the brief details of both projects.

Table 1. Synopses of the Projects

AM-WATCH (am-watch.org)	**SMARTT** (nsfsmart.org)
AM, also known as 3D Printing, is the latest manufacturing innovation and its use is growing in every aspect of the daily life from the jet engines to hearing aids [12]. AM represents a paradigm shift from the labor-intensive manufacturing processes to high-tech computer aided production. The low-cost of the desktop level 3D Printers and their versatile production capabilities have become a quick solution for several industries. Recent developments in design software tools, materials, machines and post processing supplies help the end users apply the AM innovations into several problems faced in industry. Today, a high number of the manufacturers are also struggling to find skilled AM workers needed for their production requirements [13].	The project SMARTT was launched in 2018. It is a collaboration among Motlow State Community College (Smyrna, TN), Tunxis Community College (Farmington, CT), and Tennessee Technological University (Cookeville, TN). Its goal is to address the need for awareness of Smart Manufacturing in the United States, and more importantly, to increase training in the workforce. The project is funded by a grant from the National Science Foundation's Advanced Technological Education directorate.

Table 2. Main Accomplishments of the Projects

AM-WATCH	**SMARTT**
• Massive Open Online Courses (MOOCs) are an emerging strategy for reaching wide and diverse audiences. MOOCs serve as a window to AM learning for students that do not have AM curricula immediately available to them. Samples from the developed MOOCs are 1) Introduction to AM, 2) AM Process Chain, 3) The Business of AM and Startups, and 4) Safety in AM [14]. • Secondary and post-secondary STEM educators need instructional aids since there are no currently available hard and soft copy materials in AM. AM for STEM Educators was developed in 2017 and its second edition was finalized and released in 2018 [15]. This edition is available for free download	• Workshops: Two on-ground workshops and one virtual workshop were conducted in 2019 and 2020. Each on-ground training workshop lasted for two days, and included the following components: ▪ Research Speakers: invited speakers presented state-of-the-art scientific research on the advances in Smart Manufacturing. ▪ Industry Speakers: the focus of industry speakers was to present cutting-edge technologies that

and use by educators. • The Golden Eagle Additively Innovative Virtual Lecture Series has been functioning for more than five years, providing short informational sessions about topical AM issues from subject matter experts. To date, a large number of online lectures have been delivered, with approximately 1,000 people having attended these. The recorded lectures are also available at a website maintained by the Center for Manufacturing Research [16]. • AM-WATCH participants designed and printed innovative/entrepreneurial work pieces during the second day of the studio workshops and rated their learning practices tied to ABET Student Outcomes at the end of the programs [17]. • Two-day, on-ground, train-the-trainer studios were organized in the states of Tennessee, Kentucky, Ohio and Washington to train STEM educators in high school and community college. The resources developed via AM-WATCH were used as an instructional supplement. Participants built their own 3D Printers provided by the project, and they designed and produced entrepreneurial parts by learning the ABET Student Outcome assessment and attainment [17][18].	are used in the manufacturing industry. Speakers came from different manufacturing industries such as Nissan Auto, Kasai North America, and Bridgestone Americas. ▪ Factory Tours ▪ Hands-On Training: The hands-on training takes place on the second day of the workshop and includes training the participants on using Arduino or Python coding for advanced manufacturing applications. • Educational Modules: Six educational modules were developed on policies and technologies of SM. • Short talks on applications of SM: The current phase of the project is developing short talks by members of industry and academia with experience in applying smart SM in real world problem-solving. • Project results, workshop proceedings, and publications as a result of the project are published on the project website.

Overview of Studio Workshops

Before the COVID-19 pandemic, all training activities were held over two days in an on-ground setting. Participants were recruited from underserved areas with the majority being STEM educators from high schools and community colleges. Participants learned about the innovative AM and SM instructional modules developed through the AM-WATCH and SMARTT Projects [14]. The workshops were in studio format to enable participants to learn and practice at the same time. In addition to the learning and practicing activities, each of the studios included a component of industrial site visits in order to expose the participants to real-world applications of the concepts they were learning.

Challenges Faced and Modifications to Instructional Delivery during COVID-19

Due to the COVID-19 pandemic, project teams for both AM-WATCH and SMARTT were not able to offer on-ground studio workshops. In spite of the willingness by educators to receive training, and the institutions to offer the studio workshops, strict institutional pandemic policies and procedures did not allow for on-ground workshops. As a solution the project teams decided to deliver the workshops using a hybrid format. Recruitment of participants was conducted as before, and the workshop was delivered mostly via Zoom. Table 3 summarizes attendee information and studio format for both projects.

During the virtual and hybrid workshops, the time allotted for the hands-on activities was converted to a do-it-yourself day, and resources for the activities were provided in one session and on the project website.

Table 3. Virtual/Hybrid Workshop Components

	AM-WATCH	**SMARTT**
Location/Time	Hybrid studio conducted on January 8, 2021hosted by Tennessee Tech University	Virtual workshop conducted on December 17, 2020 hosted by Motlow State Community College
Format	Hybrid (via Zoom and in person, with social distancing)	Virtual (via Zoom)
Participants	11 Participants (6 in person and 5 virtual)	39 Participants sponsored by two institutions • Motlow State Community College: 19 • Tunxis Community College: 17

Figure 1 provides an image of the virtual studio workshop participants with organizers and guest speakers.

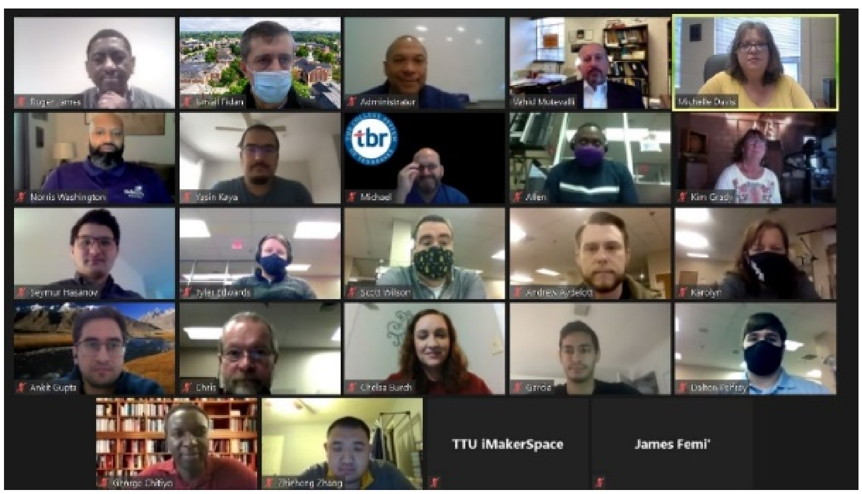

Figure 1: Image of the virtual AM-WATCH Studio Workshop Participants

Figure 2 shows the on-ground participants while they attended the day-long program, and an on-ground participant while he was working on his 3D Pen exercise.

Particularly for the SMARTT project, one advantage that came along from converting the workshop to online was the significant increase in diversity of participants as compared to before-pandemic workshops. While only two and three states were represented in the first and second workshops consecutively, 18 states were represented in the third workshop. Almost similar advertising efforts were made for all three workshops, with more outreach efforts made to regional institutions for the first and second workshops than for the third workshop.

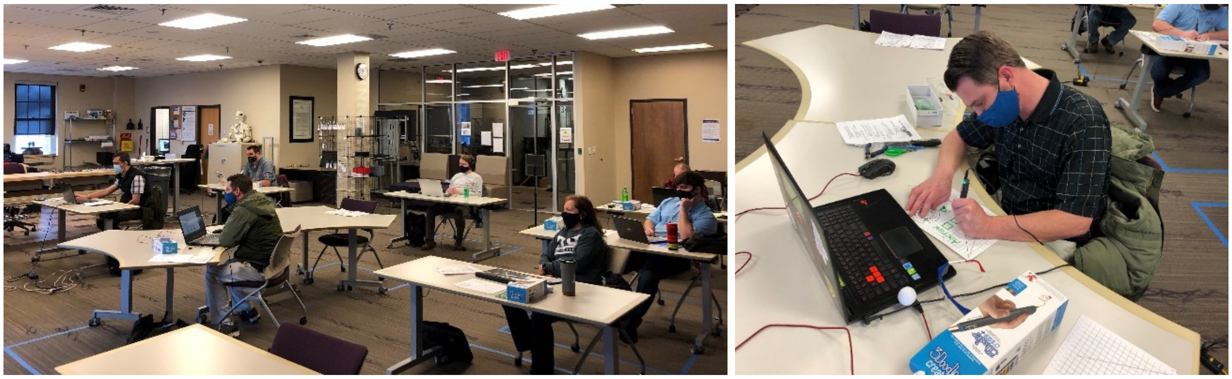

Figure 2: On-ground AM-WATCH Studio Workshop Participants with Social Distancing and Use of Mask (Left). An on-ground AM-WATCH Studio Workshop Participant working on his 3D Pen exercise (Right).

Despite the increase in diversity by state, the online workshop saw a noticeable decrease in applicants from high schools compared to higher education institutions. This is reflected in the lower percentage of high school participants compared to the first and second workshops (only six participants in the third workshop compared to 15 participants in the combined first and second workshops). Racial and gender diversity were also more apparent in the online workshop. Table 4 provides the profile of SMARTT workshop participants.

Table 4. SMARTT Workshop Participant Distribution by State

State	1st Workshop Farmington, CT	2nd Workshop Smyrna, TN	3rd workshop Online	State	1st Workshop Farmington, CT	2nd Workshop Smyrna, TN	3rd Workshop Online
AL	0	3	1	NJ	0	0	3
CT	16	0	8	NY	0	0	4
FL	0	0	1	NC	0	0	1
GA	0	0	2	OH	0	0	3
IL	0	0	1	PA	0	0	1
IN	0	0	3	RI	0	0	2
KY	0	1	0	TN	0	14	3
LA	0	0	2	TX	0	0	1
MD	0	0	1	VT	0	0	1
MA	2	0	0	WA	0	0	1

Evaluation Findings

The External Project Evaluator designed a retrospective pretest survey instrument to assess several aspects of the workshops including satisfaction with the overall workshop logistics, content, delivery methods, and the effectiveness of the workshops. The instruments also had sections which assessed specific workshop objectives, and participants were asked to rate their perceived improvement on (i) their level of understanding of AM or SM concepts, (ii) proficiency level on a number of skills demonstrated during the workshop, (iii) the extent to which they felt the workshop objectives had been met, and (iv) the relevance of the content to their work. The instrument(s) contained both closed-ended and open-ended questions.

All workshop attendees completed evaluation surveys (36 participants in the SMARTT virtual workshop, and 11 in the AM-WATCH hybrid workshop). The workshop evaluation results showed an overwhelming majority of participants strongly indicating that they gained more understanding of both AM and SM.

SMARTT Summary of Evaluation Findings

A total of 36 participants responded to the survey. There was a total of 15 (42%) ethnic minority participants participating in the workshops. Of the 36, 54% (*n* = 20) were male, 42% (*n* = 15) were female and one participant identified as non-binary. Among key evaluation findings, the majority of attendees' understanding of each topic improved. Figure 3 is a plot of the highest ratings. Across all topics presented, the majority of participants expressed that their understanding had improved "A lot better than before." Responses to open-ended survey items largely indicated that the educators really liked the aspect of having industry partners presenting during the workshops and illustrating how SM concepts were applicable to real world situations. For the online workshop, comments indicated the need for more hands-on training tailored to the online nature, as compared to the on-ground workshop.

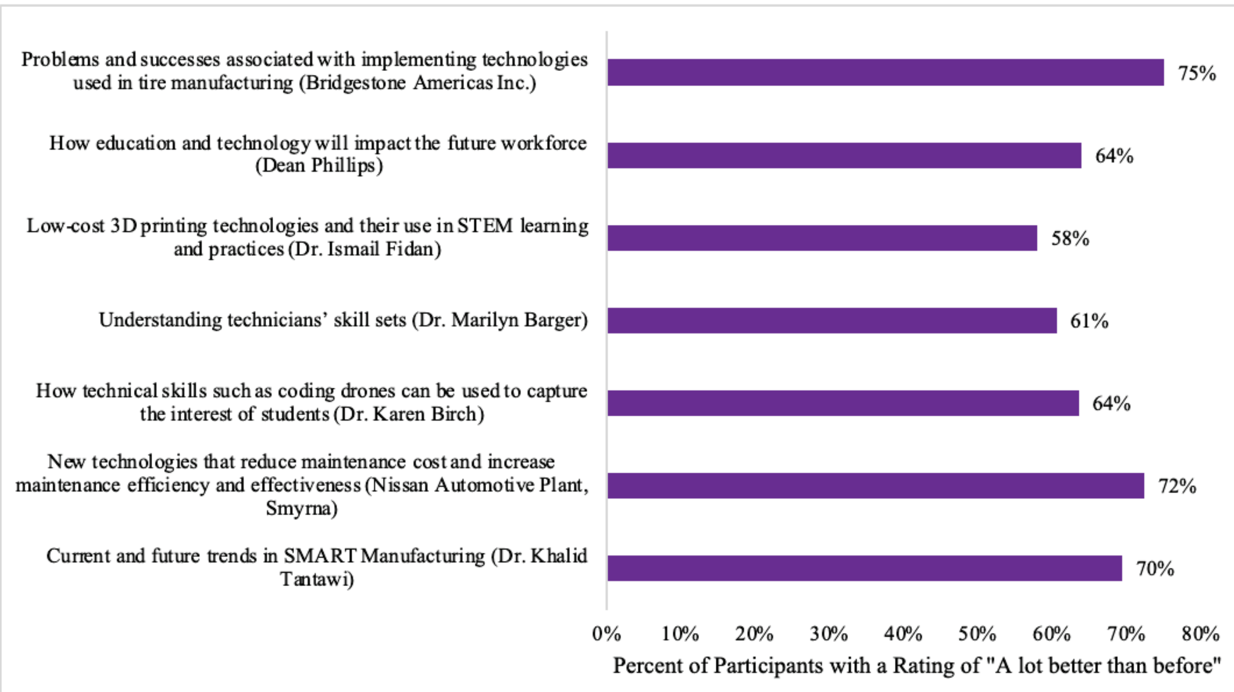

Figure 3: SMARTT Participants Indicating High Ratings of Understanding Specific Aspects Compared to Before the Workshop

AM-WATCH Summary of Evaluation Findings

Five of the participants attended in person, and six attended virtually via Zoom. Of the 11 participants, nine (82%) were male, and two (18%) were female. The racial breakdown was 64% White (*n* = 7), 27% (*n* = 3) Black or African American, and 9% (*n* = 1) Hispanic.

Figure 4 shows the change in participants' proficiency to perform 3D printing tasks, comparing their ability before and after the workshop. Top-2 box scores were computed for each of the items, which were rated on a 4-point Likert scale with the levels of minimal, basic, proficient, and advanced. There was an improvement on all the aspects measured. The biggest change (45%) was on two items (i) how to create templates and, (ii) using stencils and templates. The three remaining items each showed an improvement of 37% from pretest to posttest.

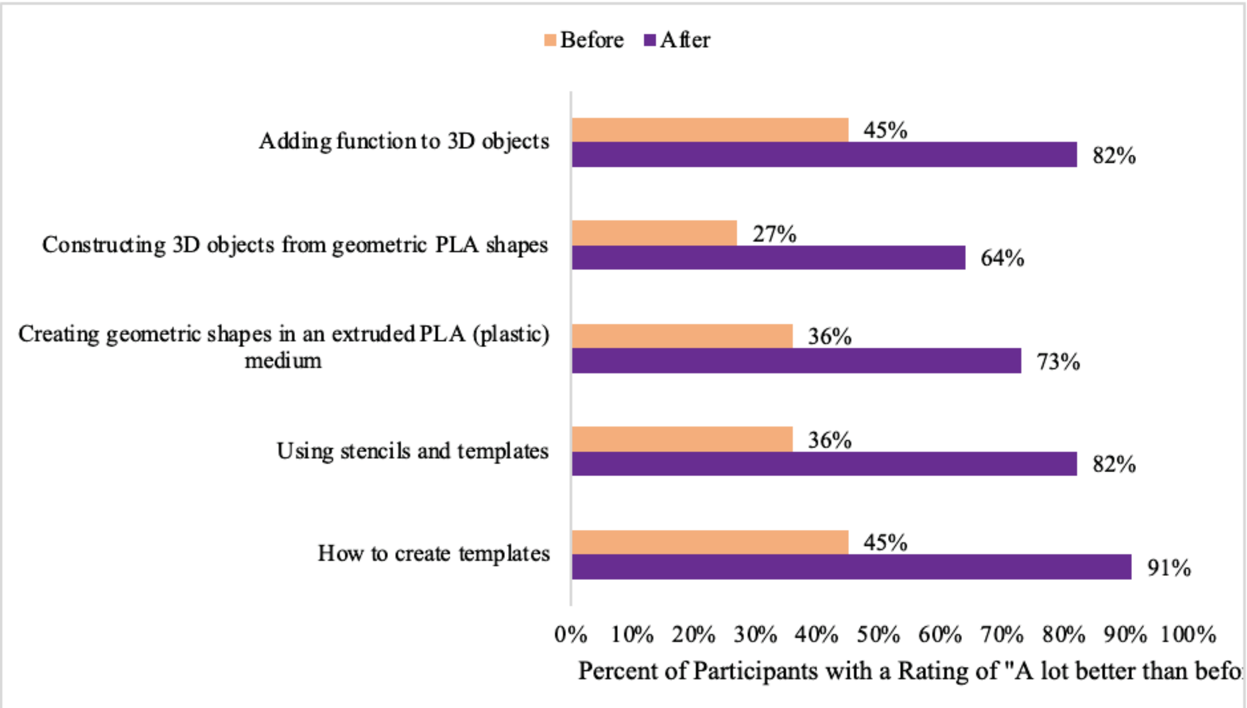

Figure 4: Participants' Proficiency with 3D Printing

All 11 participants indicated that they were both (i) likely to use what they learned during the workshop, and (ii) confident that they can successfully use what they learned during the workshop. For likelihood to use what they learned, the net promoter score was 82% with a detractor score of zero. Similarly, for confidence to successfully use what they had learned, the net promoter score was also 82%, with a detractor of zero.

Conclusions

Findings from the evaluation of both the AM-WATCH and SMARTT workshops indicated quite successful training experiences. The educators largely expressed that they benefited from the training and that they were looking forward to implementing and sharing what they learned from the workshop while engaging their students. All stakeholders would have preferred an on-ground workshop, but circumstances like COVID-19 would not permit. This was expressed both in personal communication the Project Evaluator had with various stakeholders, as well as by participants in the open-ended survey question, "In what ways could this workshop be improved?" Overall, the virtual workshops were a success.

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