Additive Manufacturing Studios: a New Way of Teaching ABET Student Outcomes and Continuous Improvement

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Tom is a Professor of Mechanical Engineering Technology at Sinclair Community College. His areas of focus are design and manufacturing of products in the MET program curriculum. Tom serves as a Co-PI for the NSF funded AM-WATCH project. He provides guidance on design and curriculum development on additive manufacturing. Tom also serves as the Principal Investigator on the NSF funded STEM Guitar Project. He also manages the guitar manufacturing lab @ Sinclair which produces over 1700+ guitar kits a year for the STEM guitar project distributed across the United States. A PLTW affiliate professor for IED, NISOD Teaching Excellence award winner, Certified Autodesk instructor and ETAC-ABET Commissioner, and text book author, Tom has taught both at the high school and collegiate levels.

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Jamshid Moradmand is a Professor of Mechanical Engineering Technology at Sinclair Community College in Dayton, Ohio. Jamshid is currently working on his Ph.D. dissertation in the area of nanotechnology and compliant mechanisms. He worked in the automotive industry as a design/development engineer for seventeen years prior to becoming an educator. Jamshid's work and research in the automotive controlled brake systems and suspension systems have provided him with a good understanding of the automotive components. He holds numerous patents and trade secrets in the field of automotive brakes and suspensions.

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1. Abstract

The Additive Manufacturing Workforce Advancement Training Coalition and Hub (AM-WATCH) targets to address gaps in the current knowledge base of manufacturing professionals through the development of Massive Open Online Courses (MOOCs) based educational materials, delivery of professional development activities, support provided to 30+ instructors per year, and expanded outreach activities targeting K-12 and community college teachers and students. Tennessee Tech University is collaborating with the University of Louisville, Sinclair Community College, National Resource Center for Materials Technology Education, Oak Ridge National Laboratory, and industry in the development of cutting-edge and multi-dimensional educational modules and activities for instructors. Developed materials are presented to 30+ instructors through intensive two-day AM Studios every year. While instructors learn the latest trends and technologies in AM, they also grasp the ABET Student Outcomes and Continuous Improvement. This paper reports the current practices made in these studios and feedback received from the instructors.

2. Introduction

AM is the industrial standard term (ASTM F2792) for all applications of this latest production technology which is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer[1]. Rapid Prototyping (RP) and 3D Printing (3DP) are often used synonymously with AM[2]. 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.

The utilization of desktop printers is increasing daily in every level of life from offices to labs, art, medicine, and dentistry. With the increased national and global focus, there is clear evidence of the strong and growing demand for experts in AM in the US. The AM-WATCH hub's purpose is to help fill the skill gaps in AM professionals' training through curricular modules, expanding the AM reach and coordinating with experts in the field as advisors. This project is a collaboration with Community Colleges, Universities, a National Lab, and industries[3,4]. Other than providing various cutting-edge information, AM-WATCH Project also trains the educators with the instructions of how to build a 3D Printer knowledge and confidence.

In each cohort of the AM-WATCH Project, developed materials and the latest AM technologies are introduced to STEM educators selected from the various educational institutions in the US.

During the selection process, priority is given to the STEM educators who are from the under-represented groups and also those from underserved areas. The workshops are delivered in a Studio format so that 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 approach. 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 things[5].

While studio attendees learn the latest trends and technologies in AM they also gain valuable skill sets about the 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[6]. ABET's criterion 4 on continuous improvement is explained and examples are provided. 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 this paper, authors present the structure of the studios and evaluation results showing the ABET student outcome attainment, and the results drawn.

3. AM Studios

In each project cohort, two studio based hands-on workshops are organized. Figure 1 presents the sample day 1 list of activities held in the Knoxville studio in May 2017. The main objective of the workshops is to deliver the currently developed curricular 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 and run a project as in teams of about 3-4 members. Other than many valuable presentations and industry tours, each team presents their accomplishments at the end of the program.

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) are presented to attendees. A template presentation is given, and the expected outcomes of the project are detailed. Coaching is also provided throughout their work on the project as exemplified in Figure 2.

The ABET Criteria for Accrediting 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 Criteria 2 and 3. And, this whole process is considered as Criterion 4[7].

Tennessee TECH

2017 NSF Additive Manufacturing Studio
Knoxville, TN

AGENDA

DAY ONE: Saturday, May 20, 2017

TIME	SESSION	LOCATION
8:00-8:30 a.m.	**Breakfast and Welcoming** • All Attendees	Conference Room A
8:30-9:15 a.m.	**Review of the Workshop Agenda, Introductions, & Workshop Deliverables** • Ismail Fidan and Nick Russell, Tennessee Tech University	Conference Room A
9:15-9:45 a.m.	**Makerspaces: Transforming from Consumers to Producers** • David Voetmann, The Facility Makerspace, Edmonds Community College	Conference Room A
9:45-10-15 a.m.	**Where Additive Manufacturing Begins … The Design** • Professor Tom Singer, Sinclair Community College	Conference Room A
10:15-11 a.m.	**State of the Additive Manufacturing Industry and Q&A** • Terry Wohlers, Wohlers Associates	ZOOM Connection from Conference Room A
11:00-11:15 a.m.	**Break**	Conference Room A
11:15 a.m.-Noon	**Additive Manufacturing for Production** • Ed Tackett, University of Louisville	Conference Room A
Noon-1:00 p.m.	**Networking Lunch** • All Attendees	Conference Room A
1:00-1:30 p.m.	**AM MOOCs, AM Additively Innovative Lecture Series and Task Assignment for Studio Practices** • Ismail Fidan, Tennessee Tech University	Conference Room A
1:30-2:00 p.m.	**Technology Made Simple** • Brooks Partain, Global Strategic Account Manager	ZOOM Connection from Conference Room A
2:00-3:30 p.m.	**Set up, run, and test participant's 3D printers** • All Attendees	Conference Room A
3:30-4:00 p.m.	**Driving to Protomet** protomet.com 1010 Larson Drive, Oak Ridge, TN 37830 • All Attendees	Carpool to Protomet
4:00-5:00 p.m.	**Tour of Protomet** • Dan Sherwood, Protomet, Cell 865.696.7217	Protomet
5:00-5:30 p.m.	**Driving back to TCAT-Knoxville** • All Attendees	TCAT-Knoxville at 1100 Liberty Street, Knoxville, TN 37919
5:30-7:00 p.m.	**Honorary Dinner provided by Coulter & Justus, P.C. and BB&T** • All Attendees, and Mike Parton and John Harris	Conference Room A

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Figure 1: Day 1 Activities of the Knoxville AM Studio

Figure 2: A group of STEM instructor building a 3D Printer

The Criteria (3 and 4) for Accrediting Engineering Technology Programs are given in 3.1 and 3.2. They are Effective for Reviews During the 2017-2018 Accreditation Cycle.

3.1. Criterion 3: Student Outcomes

The program must have documented student outcomes that prepare graduates to attain the program's educational objectives. There must be a documented and effective process for the periodic review and revision of these student outcomes.

Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students attain as they progress through the program. Program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. The objectives are based on the needs of the program's constituencies.

For purposes of this section, broadly defined activities are those that involve a variety of resources; that involve the use of new processes, materials, or techniques in innovative ways; and that require a knowledge of standard operating procedures. Narrowly defined activities are those that involve limited resources, that involve the use of conventional processes and materials in new ways, and that require a knowledge of basic operating processes.

For associate degree programs, these student outcomes must include, but are not limited to, the following learned capabilities:

a. an ability to apply the knowledge, techniques, skills, and modern tools of the discipline to narrowly defined engineering technology activities;
b. an ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require limited application of principles but extensive practical knowledge;
c. an ability to conduct standard tests and measurements, and to conduct, analyze, and interpret experiments;
d. an ability to function effectively as a member of a technical team;
e. an ability to identify, analyze, and solve narrowly defined engineering technology problems;
f. an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
g. an understanding of the need for and an ability to engage in self-directed continuing professional development;
h. an understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity; and
i. a commitment to quality, timeliness, and continuous improvement

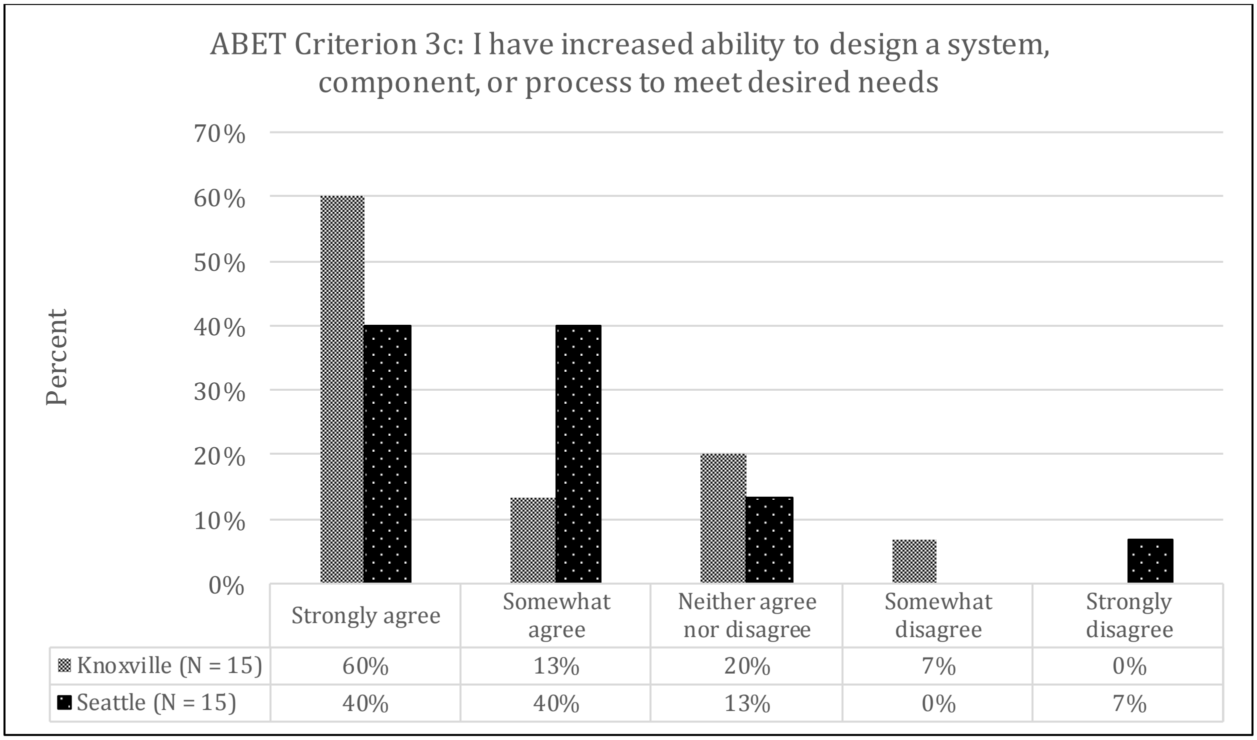
3.2. Criterion 4: Continuous Improvement

Continuous improvement is a corner stone of a quality engineering or engineering technology program. ABET requires that a well-structured and implemented continuous improvement plan should be in place[8]. ABET's definition for the Criterion 4, Continuous Improvement is given below.

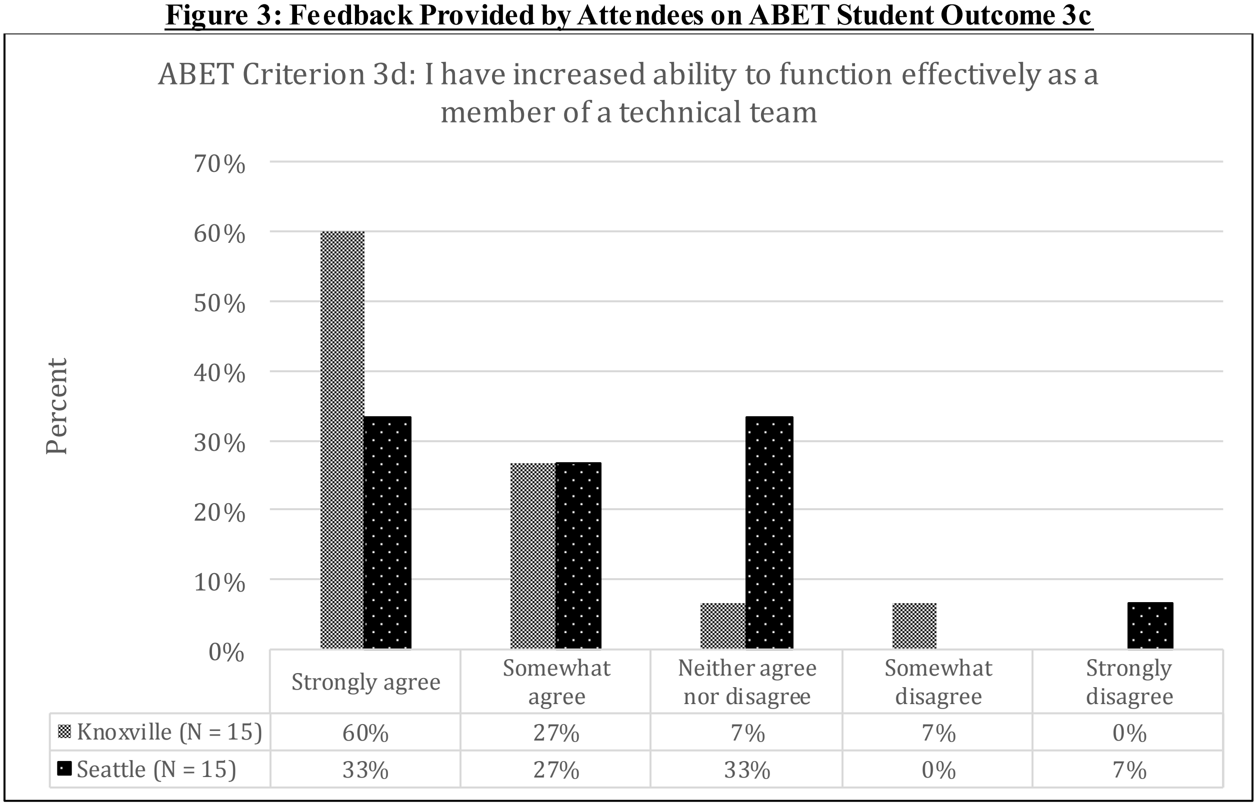
The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program. Other available information may also be used to assist in the continuous improvement of the program.

4. Feedback Received from the Attending Instructors

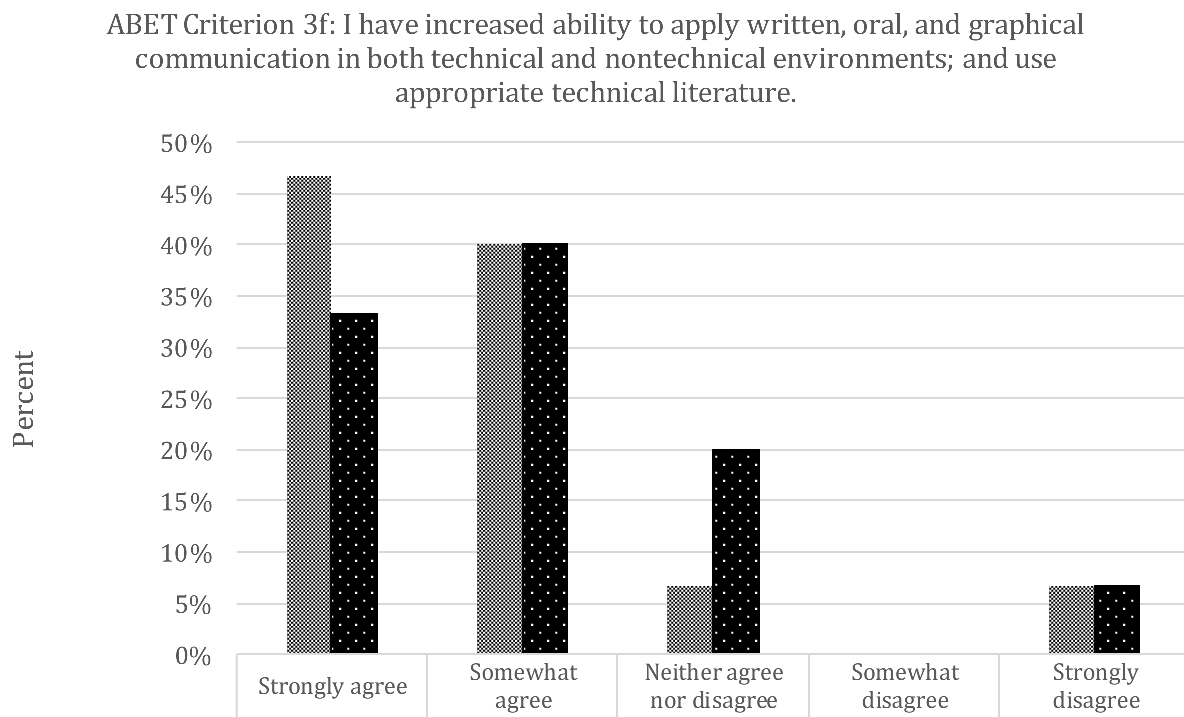
The project evaluation team administered an evaluation survey tool to all workshop attendees at the end of the program. The results provided below are figures and tables corresponding to responses to each of the five ABET criteria that were evaluated for two workshops held during summer 2017, one in Knoxville (TN) and the other in Seattle (WA) workshop participants. Responses for the two workshops are presented side by side for each ABET criterion.



<u>Figure 3: Feedback Provided by Attendees on ABET Student Outcome 3c</u>

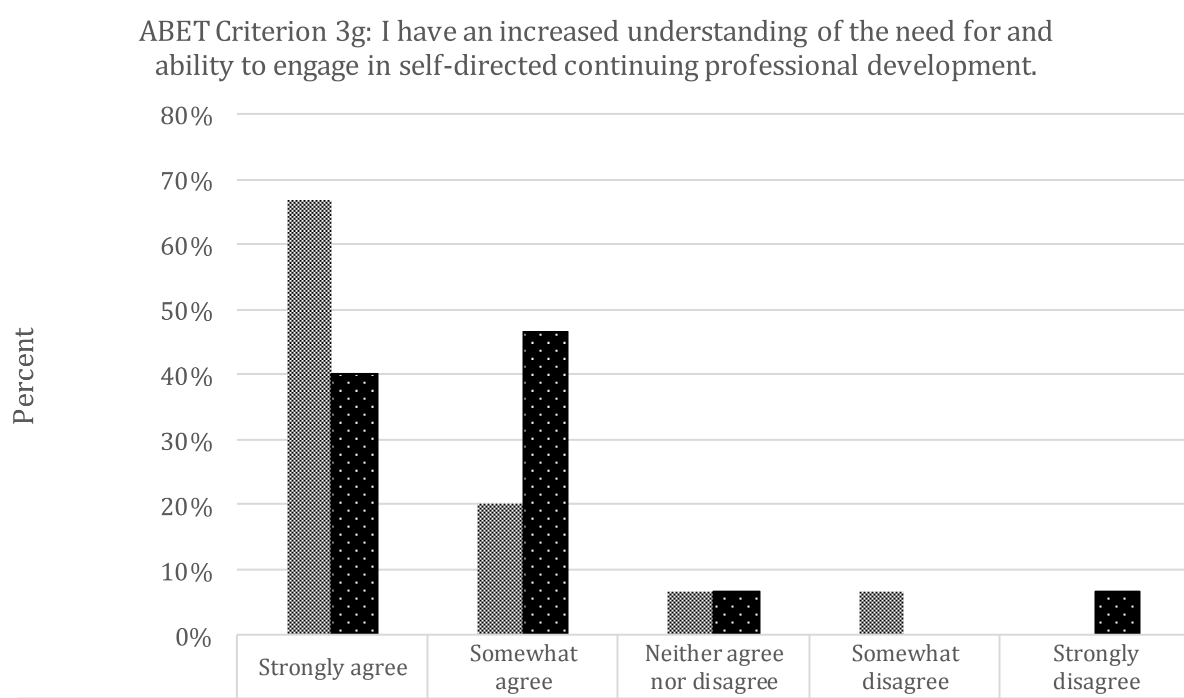


<u>Figure 4: Feedback Provided by Attendees on ABET Student Outcome 3d</u>



	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Knoxville (N = 15)	47%	40%	7%	0%	7%
Seattle (N = 15)	33%	40%	20%	0%	7%

Figure 5: Feedback Provided by Attendees on ABET Student Outcome 3f



	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
Knoxville (N = 15)	67%	20%	7%	7%	0%
Seattle (N = 15)	40%	47%	7%	0%	7%

Figure 6: Feedback Provided by Attendees on ABET Student Outcome 3g

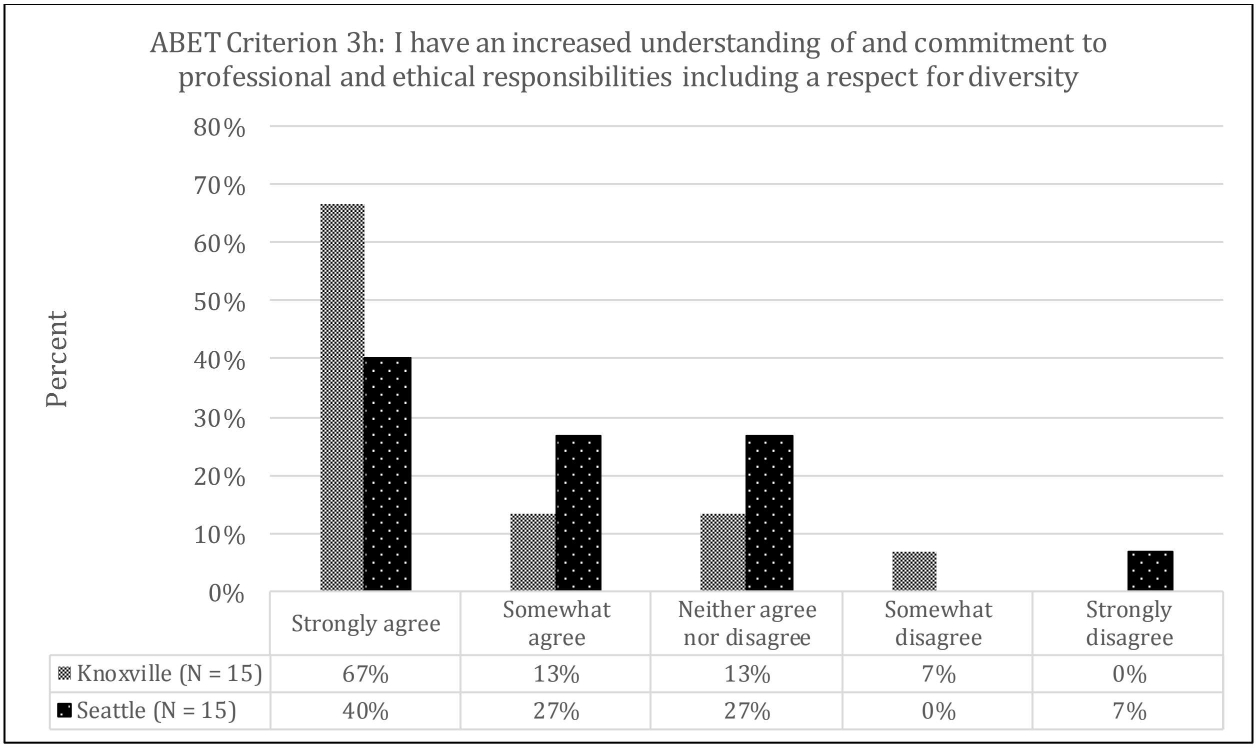


Figure 7: Feedback Provided by Attendees on ABET Student Outcome 3h

As evident in Figures 3 through 7, workshop participants indicated high satisfaction rates on each of the ABET criteria. What we have also found is that the relationship is strong between the ABET accreditation skill sets that are measured and the training that was provided through the AM-WATCH project. These industry related skills are not only important to programs considering being accredited and those currently accredited, but also to employers that are hiring graduates of programs.

Table 1 presents summary findings of the quantitative evaluation of each of the two studios. The results of the workshop evaluation showed that the satisfaction of the workshop attendees was high, the content that was presented was relevant to their work, and that their grasp on the ABET student outcomes and continuous improvement was also very promising.

Participants were given the opportunity to add their reflections on the studio workshops. Asked about what they liked the most about the workshop, a recurrent comment was that they enjoyed the opportunity to interact with educators from other institutions and professionals in the field of AM. Another major highlight was the usefulness of the hands-on aspect of the workshops, including the process of putting together the 3D Printers as well as the chance to design an object of interest.

When asked what they would recommend changing about the workshops, a few participants suggested to (i) allocate more time towards the hands-on activities (ii) reduce the number of “talks” by presenters, and (iii) add a component of training related to the design aspect as well. Most participants indicated "nothing" when asked what they would recommend changing. Most of the participants' sentiments are captured in the following comments: "Overall, I am happy to have attended. I have a better understanding of AM. Networking was extremely helpful" (Knoxville participant), and "Well done! Excellent content! Keep up the good work!" (Seattle participant).

Table 1: Summary of Evaluation Findings for the two Studio Workshops

Knoxville (TN) Studio	*Seattle (WA) Studio*
• 100% of participants agreed (strongly or somewhat) that the training experience will be useful in their work. • 93% of participants agreed (strongly or somewhat) that the training objectives were clearly defined, the training objectives were met, and the topics covered were relevant to their profession. • 93% of participants agreed (strongly or somewhat) that the quality of logistic and administrative support had a positive impact on the experience, the quality of instruction was excellent, the training materials/handouts distributed were helpful, and the facilities were adequate and comfortable. • 87% of participants agreed (strongly or somewhat) that each session stated the objectives clearly and the time allotted for each session was sufficient. • 80% of participants agreed (strongly or somewhat) that the content of the training workshop was what they expected.	• 100% of participants agreed (strongly or somewhat) that the training objectives were met, that the topics covered were relevant to their profession, and that the training materials/handouts distributed were helpful. • 100% of participants agreed that the quality of logistic and administrative support had a positive impact on their experience at this workshop and that the quality of instruction was exceptional. • 93% of participants agreed that pre-program logistics, support, and information were useful and thorough. • 93% of participants agreed that the training objectives were clearly defined and, that the training experience will be useful in their work. • 87% of participants agreed that each session stated the objectives clearly and that the meeting room and facilities were adequate and comfortable. • 80% of participants agreed that the content of the training workshop was what they expected.

5. Conclusions

Utilization of AM technologies is continuously increasing in every aspect of the life lately. Although there are a number of professional development activities available in this advancing technology, cost and time related concerns make it difficult to attend for anybody who has an interest to learn the impact of this technology for the classrooms and laboratories. AM-WATCH provides a hands-on Studio type learning environment for the STEM educators who want to implement this technology in their classrooms and laboratories. This paper presents the success stories of the AM Studios delivered in Knoxville and Seattle in 2017. Attendees' grasp of ABET Student Outcomes and Continues Improvement was an essential part of the Studios, and participants practiced these concepts in a techno-entrepreneurial project environment. The evaluation results of the workshop attendees showed that each attendee gained valuable skills and learned a lot pertaining to ABET Criteria on Student Outcomes and Continuous Improvement.

6. Acknowledgements

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