Effectiveness of Train-the-Trainer Workshops in Intelligent Industrial Robotics

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***Abstract*— In this work we investigate the effectiveness of two train-the-trainer workshops on intelligent industrial robotics. The two workshops, which took place in summer 2021 in Tennessee and Alabama, were the first of a series of six workshops. A total of 32 persons applied to the two summer workshops from 10 states, of whom 15 attended and successfully completed the workshops. Evaluation results show that the participants' knowledge on industrial robotics significantly improved after the workshops, and the vast majority indicated that the training will be used in their home institutions. The major challenge faced during the workshops was the spread of the delta variant of CoVid-19 at the time the workshops were scheduled to take place, and the wide diversity of the educational background of participants.**

Keywords—Intelligent Industrial Robotics, Train-the-trainer, CoVid-19 Pandemic

I. Introduction

The year 2020 marked a cornerstone in the history of industrial robotics, with the Electronics industry becoming the largest market of industrial robots [1], a position that had historically been held by the automotive industry [2] [3] (Table 1 below). In addition to that, the metal and machinery, Chemicals, and the food industries witnessed rapid growths in the demand for industrial robots in the last few years.

Furthermore, the need for industrial robotics sharply increased with the Covid-19 pandemic, due to the added demand for no-contact material handling in applications beyond the manufacturing industry [4]. One of the major impacts of the pandemic was the exposure of the urgent need for more preparedness in developing self-sufficiency in the supply chain [5] [4] [6]. As a results, the supply chain disruptions seen during the pandemic have abruptly accelerated the use of next-generation intelligent robotics [7] [3].

TABLE I. INDUSTRIAL ROBOTICS MARKET BY INDUSTRY

Market share of industrial robotics by industry		
Industry	***2020***	***2016***
Electronics	53.8%	36.9 %
Automotive	23%	41.7 %
Metal and Machinery	16.2%	11.6 %
Plastics and Chemicals	4.3%	6.5%
Food	2.6%	3.3%
Pharmaceuticals	0.9%	0

Moreover, the latest report from the International Federation of Robotics executive summary for 2021 shows that a robotics revolution continues to take place in East Asia, particularly in China, which as of 2021 dominates more than half of the robotics market in the top 10 countries as shown in Fig. 1. However, with the growing demand for industrial robotics, the need for trained individuals that can handle these machines has also increased rapidly, and is expected to intensify with the introduction of artificial intelligence in robotics. Prior to the pandemic, the Intelligent Industrial Robotics market was expected to grow to $14.29 billion in 2023 from $4.94 billion in 2018 [7] [8].

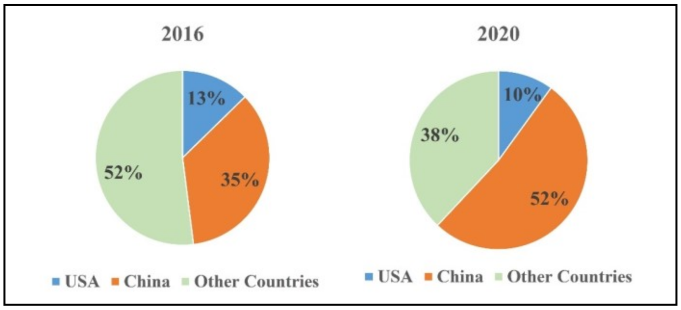

Fig. 1. Industrial robotics market in the top 10 countries.

Okuda et al. in [8] outline four technological aspects in industrial robotics that utilize artificial intelligence, which consequently increases their flexibility: Collision avoidance, Conducting Human-Robot Cooperative (HRC) tasks [8] [9], 3D vision and sensing, and Force inspection and control. The next-generation of industrial robotics, known as Collaborative robots (cobots), are based on machine intelligence, they are more compact in size than traditional industrial robots. They are equipped with advanced sensing systems to sense human presence around them. Reports indicate that deploying co-bots resulted in increased production in some of the major automotive manufacturers (Toyota, Ford, and Mercedes Benz) [10]. The IFR forecasts that collaborative robots will take the lead in the robotics industry in the upcoming years [11]. During the Covid-19 pandemic, cobots can support the implementation of social distancing in factories [12].

With the significant increase in demand for industrial robotics, particularly, a work force that is capable of handling the advances in this technology is needed. One way to achieve workforce preparedness is to target faculty of institutions on the secondary and tertiary education level. In this paper, we investigate the effectiveness of two train-the-trainer workshops on intelligent industrial robotics that targeted faculty of Science, Technology, Engineering, and Manufacturing (STEM) in secondary and tertiary education institutions.

II. Materials and Method

Two workshops were developed and offered to STEM faculty in summer 2021. The workshops were two days long, and included speakers, factory tours, and hands-on training on intelligent industrial robotics. One workshop was offered at Chattanooga State Community College in Chattanooga, TN and the other was offered at Lawson State Community College in Bessemer, AL.

All training was conducted on-ground, a CR-7*i*A/L collaborative robot unit by Fanuc was the primary training unit that was used for the workshop at Chattanooga, TN and a Sawyer collaborative robot by Rethink Robotics was the primary training unit used for the workshop in Bessemer, AL. Other industrial robot units that were used or demonstrated during the training include Motoman HP3JC, ABB IRB 140, KUKA KR5sixx R650, and Fanuc S-430*i* (see Fig. 2).

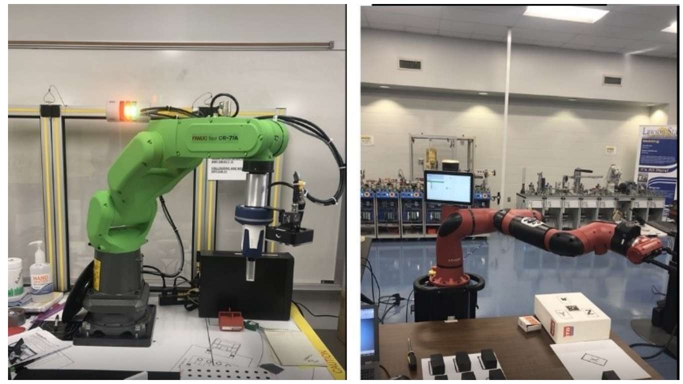

Fig. 2. The Fanuc CR-7iA/L (Left) and the Rethink Robotics Sawyer (Right) collaborative robots were used for the training.

The technical specifications for the two intelligent robot units that were used in the training are shown in table 2 below:

TABLE II. Technical Specifications of the Intelligent Industrial Robotic Units Used for the Training.

Technical Specifications of the two robots used in the training		
Robot Name:	***CR-7iA/L robot***	***Sawyer robot***
Manufacturer:	Fanuc	Rethink Robotics
Mass:	55 kg	19 kg
Maximum Payload:	7 kg	4 kg
Maximum Reach:	911 mm	1260 mm
Number of Axes:	6	7
Repeatability:	± 0.01 mm	± 0.1 mm
Maximum TCP Speed:	1000 mm/s	2000 mm/s

Participation in the workshops was open to all high school and two-year college faculty across the nation. Applications for the workshops were done online through the project's website. Recruitment for the workshops particularly targeted community and technical colleges in the states of Tennessee and Alabama.

III. Results and Discussion

A. Workshop Demographics, Diversity, and Inclusion

Despite being in the wake of the spread of the Delta variant of the CoViD-19 causing virus, a total of 32 applications were received for workshops from 10 states of whom 15 participated and successfully completed the workshops.

The spread of the delta variant in summer 2020 affected the participation rate of the confirmed applicants. However, it can be seen from the demographic data that diversity was very well represented by the participants, with participations coming from five states. Demographics of the applicants are shown in Table III.

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TABLE III. Demographic data for applicants to the Intelligent Industrial Robotics workshops.

Demographic data for workshop applicants	
Demographic:	***Number of applicants***
Applicants by State:	10 states: Alabama, Florida, Indiana, Louisiana, New Jersey, New York, Ohio, Tennessee, Washington
Applicants by Sex:	
Female:	10 (31%)
Male:	21 (66%)
No answer:	1 (3%)
Applicants by highest degree achieved:	
PhD or Doctoral	9 (28%)
Masters +	12 (37%)
Bachelors degree	1 (3%)
Associate degree	5 (16%)
High school degree	5 (16%)
Total:	32 (100%)

Demographic data of the workshop participants are shown in Table IV below. Pictures from the two workshops are shown in Fig. 3.

TABLE IV. Demographic data for participants in the Intelligent Industrial Robotics workshops.

Demographic data for workshop participants	
Demographic:	***Number of participants***
Participants by State:	Five states: Alabama, Florida, Indiana, Louisiana, Tennessee
Participants by Sex:	
Female:	5 (33.3%)
Male:	10 (66.7%)
Applicants by highest degree achieved:	
PhD or Doctoral	4 (26.7%)
Masters +	5 (33.3%)
Bachelors degree	0 (0%)
Associate degree	2 (13.3%)
High school degree	4 (26.7%)
Participants by Race:	
American Indian	0
Asian	0
Black or African American	5 (33.3%)
Hispanic	1 (6.67%)
White	9 (60%)
Total participants:	15 (100%)

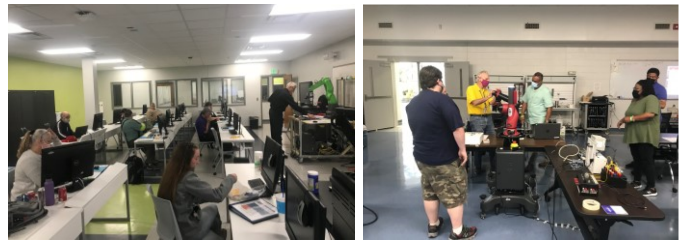

Fig. 3. Participants in the first intelligent industrial robotics workshop in Chattanooga, TN (Left), and in the second workshop in Bessemer, AL (Right).

From Table IV, it can be seen that there is a considerable ratio of participants from under-represented groups in the workshops when compared to the national average for the engineering workforce.

The presence of under-represented groups (American Indians, Blacks, Hispanics, and Women) in engineering continues to be a major concern in the United States. According to the American Society for Engineering Education (ASEE), by 2019 women constituted only 14% of the engineering workforce in the U.S. Racial and ethnic under-represented groups (Native Americans/Native Alaskans, Hawaiian/Pacific Islanders, Blacks, and Hispanics) constituted only 13% of the engineering workforce [13].

Table V below shows the demographic data of the share of each under-represented group in the engineering workforce compared to its ratio of the U.S. population. Data is taken from the National Center for Science and Engineering Statistics (NCSES) for 2019.

TABLE V. Presence of Under-represented Groups in Engineering in the U.S. in 2019 [14].

Demographic data for workshop participants		
Demographic group	***Engineering Workforce (%)***	***% of U.S. Population***
American Indian/ Native Alaskan, other races/ more than one race	< 1.60 %	1~ 2 %
Black or African American	5.37 %	12.54 %
Hispanic or Latino	7.92 %	18.45 %
Female	13.75 %	50.75 %

* Data is taken from Tables 1-2, 9-2 and 9-3 of the NCSES report for 2019 then converted to percentage.

The significantly higher presence of black participants in the train-the-trainer workshops (33.3 %) when compared to the national average in the engineering workforce is due to the recruitment efforts made by the project team in Historically Black Colleges and regions of high presence of under-represented groups in central Alabama and southeast Tennessee.

The low presence of Hispanic and Native American participants (only one participant and no participants consecutively) is due to the absence of Hispanic-serving and Tribal colleges in the states of Tennessee and Alabama, where recruitment efforts concentrated.

B. Evaluation of the Effectiveness of the Workshops

To align with best practices, two methods were used to evaluate the effectiveness of the workshops:

1. Direct assessment of participants by pre-workshop and post-workshop assessment exams.
2. Indirect Assessment through post-workshop evaluation surveys that included both multiple choice questions and open-ended questions.

All evaluations were administered by the independent evaluator. To comply with federal requirements on research ethics, participants had the option to decline to answer any question on the surveys [15]. In total 14 out of the 15 participants responded to the pre-workshop surveys, and 12 participants responded to the post-workshop surveys. Results of the surveys are shown in table V below.

TABLE VI. WORKSHOP SURVEY RESULTS.

Demographic data for workshop participants		
Metric	***Total Responses***	***Average Score***
Pre-Workshop Technical Assessment Test	14	12.2 %
Post-Workshop Technical Assessment Test	12	64.4 %
Post-Workshop Evaluation Survey:	***Total Responses***	***Strongly Agree or Agree***
My skills/knowledge increased as a result of participating in this workshop?	12	11 (92%)
Workshop activities were appropriate and reasonable in the time allowed.	12	9 (75%)
Did the workshop give you a skill or skills that will help in your profession?	12	8 (67%)
Your knowledge increased as a result of the workshop	12	10 (83%)

Some of the comments that were received on the open-ended question include:

“The materials presented where broken down to assure understanding by all levels of knowledge of workshop attendees.”

“I enjoyed the hands on activities. I also enjoyed the information and the friendly instructors. They provided a lot of important information.”

“I love the workshop overall. However, the hands-on portion of the workshop, learning to program the robots, was my favorite.”

From the assessment results, it can be seen that there is a significant improvement in the technical knowledge gained by the participants as evidenced by the improved score from 12.2% to 64.4%.

C. Challenges and Room for Improvement

The main challenge that was faced by the project team was that the participants came from widely different backgrounds ranging from PhD/ Doctoral degree holders in engineering fields to High-School degree holders in other STEM fields. To accommodate for the wide background knowledge, the workshop instructors had to adjust the activities levels and divide the participants into groups by experience in the field.

D. Impact of CoVid-19

At the time the workshops were scheduled, cases of CoVid-19 in the States of Tennessee and Alabama were declining steadily. At the time the first workshop took place in June 2021, the State of Tennessee reported the lowest number of cases since the start of the Covid-19 Pandemic. However, at the time the second workshop took place in July 2021, the United States witnessed the beginning of the delta variant wave of CoVid-19, which considerably affected the participation of applicants from farther states. Measures taken to limit exposure to CoVid-19 included temperature scanning prior to entering institutional facilities, seating participants six feet apart, and wide presence of hand sanitization stations and face masks throughout the training facilities. All factory tours were cancelled during the workshops.

IV. CONCLUSION AND FUTURE PERSPECTIVES

In this work we analyze the effectiveness of two train-the-trainer workshops that were offered in summer 2021 in Tennessee and Alabama on intelligent industrial robotics. The training targeted educators in secondary and tertiary educational institutions in the two states and nearby states. One of the objectives of the workshop training was to increase the knowledge of intelligent industrial robots among students of under-represented groups. The two workshops were the first of a series of six training workshops. A total of 32 persons applied to the two summer workshops from institutions in 10 states across the nation, of whom 15 attended and successfully completed the workshops. Voluntary Pre- and Post- workshop Evaluations were completed to assess the effectiveness of the workshops. Results show that the participants’ knowledge on industrial robotics significantly improved after the workshops, and the vast majority indicated that the training will be used in their home institutions. The percentage of faculty from under-represented groups that completed the workshops is higher than the percentage of under-represented groups in the engineering workforce. The major challenge faced during the workshops was the spread of the delta variant of CoVid-19 at the time the workshops were scheduled to take place.

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