Technologist Advanced Manufacturing Program (TechAMP)

Curriculum Outline

July 2024

Deliverable 2.2

Hub #1: Statistical Process Control (SPC)

Goal: In Hub #1, students will develop competencies in applying statistical process control (SPC) and related data analytics tools to monitor, diagnose, improve, and solve manufacturing process-related issues.

Learning Objectives:

- *Collect and leverage the production data to assess the stability and capacity of a given production process*
- *Investigate the effect of various production factors on the production quality*
- *Apply DMAIC methodology to solve a problem or improve a situation*

Week #1: Introduction

- Overview of manufacturing process, statistical process control, variation control procedure, run chart, statistics measures such as mean and range, and voice of customers.
- Lab: Students recognize and address measurement variations by measuring the bend angles of wires.
- Introduction to the interactive digital simulation of the injection molding manufacturing process and statistical process control.

Week #2: Manufacturing Variation

- Manufacturing variation, variation types, probability basics, histogram, statistics measures such as median, mode, standard deviation, and methods to reduce manufacturing variation.
- Lab: Students recognize, categorize, and address manufacturing variations by bending two sets of wires.
- The interactive digital simulation generates injection molding production data and guides students to visually fit histogram curves and locate statistics measures for the data.

Week #3: Control Charts

- Sampling, product inspection sampling strategy, control limits, control charts, West Electric rules, and the connection between control charts and hypothesis testing.
- Lab: Students generate control charts using the week 2 lab production data then apply the control charts to newly bent wires to assess the stability of the wire-bending process.
- The interactive digital simulation generates injection molding production data, then uses interactive graphs to let students explore control charts and the West Electric rules.

Week #4: Process Capability

- Specification limits, process capability, process capability measure threshold, and their application.
- Lab: Students calculate and assess the process capability of the wire-bending process with given specification limits; applying all the tools learned to analyze the stability and capability of a real industry manufacturing process.

Week #5: Root Cause Analysis (RCA)

- RCA tools (Pareto chart, Ishikawa diagram, 5 why method) and their applications in statistical process control settings; introduction to the Six-Sigma DMAIC problem-solving framework.

- Lab: Students apply RCA tools to identify the causes of wire-bending manufacturing variations and injection molding gear defects in the lab; this week emphasizes the formalism of applying the well-designed universal approaches (a portion of the lab activities will overlap with week 2 lab).

Week #6: Data Analytics Tools I

- Data analytics tools: Analysis and Variances (ANOVA), Design of Experiments (DOE), and their application in statistical process control context. E.g., ANOVA can be used to identify the important production factors for production quality, and DOE can be used to investigate the actual effect of the factors on the production quality.
- Lab: Students apply ANOVA and DOE within the DMAIC framework, to explore the impact of a small set of factors on the production quality using production data in the spreadsheet.

Week #7: Data Analytics Tools II

- Model fitting, linear regression, its connection to DOE, and its application in the context of statistical process control.
- Lab: Students fit the model and analyze the effect of a set of manufacturing factors on production quality using production data in the spreadsheet.

"Practical" DOE Breakdown:

- Make sure process is in control
- Full factorial design
    - Why you need to explore full parameter space, framework for how to test the outcome of different combinations
    - Suggested initial values to take (+1, 0, -1 or high, medium, low)
- How to interpret results (from software) to predict optimal solutions
    - If there is time, do a finer sweep on most important parameters
- Validation, test the solution
- **Goal:** Students will be able to use a framework and methodology to design controlled experiments which will use limited resources (time, materialts) to optimize process.
- **Software:** Excel, Matlab, multi-variable regression analysis. DAVE: Could do multiple linear regressions, with simple arithmetic.

Week #8: Big Data: Comprehensive Problem Solving and Advanced Techniques

- Polynomial regression models and their application; problem-solving case studies using data analytics in the industry.
- Lab: Students use a bigger dataset, select the proper method, fit the model, and analyze the effect of a set of manufacturing factors on production quality in the data analytics software. Students will practice dealing with data with noise in this lab.

Hub #2: Manufacturing Systems

Goal: In Hub #2, building on top of the production process, students will develop competencies in managing manufacturing systems, diagnosing system-related issues, and improving manufacturing systems productivity.

Learning Objectives:

- *Evaluate the manufacturing system performance using proper measures*
- *Justify the use of the buffers in a manufacturing system*
- *Recognize the impact of solving one problem on the rest of the system*
- Propose approaches to eliminate the identified system-level waste
- Schedule production operations and workers to meet production goals and material utilization goals

Week #1: Overview of Manufacturing Systems

- Manufacturing system types, components, and performance measures.
- Lab: Students manage an in-person simulated manufacturing system to assemble LEGO Minions to identify manufacturing system components, and types, and measure the system performance using data.

Week #2: Buffers and Machine Failure

- Queue's impact on manufacturing system performance, the fact of machines being unreliable, and the function and use of buffers in a manufacturing system.
- Lab: Students play interactive digital simulations to manage a manufacturing system, troubleshoot, and solve machine failure issues utilizing buffers.

Week #3: Cause and Effect of Problems

- Discrete-event system simulations, unintended consequences of one solution to the complex, interrelated system.
- Lab: Students play interactive digital simulations to explore the impact of the solution of one problem on other pieces of the system and the overall system performance.

Week #4: Lean Manufacturing 1

- Lean manufacturing concept, Toyota production system, lean manufacturing tools (e.g., Kizen, QDIP charts, Andon lights), MUDA, and practices to eliminate/reduce MUDA.
- Lab: Students conduct **value stream mapping** practices, identify and assess the possible wasteful operations or services, explore potential changes to eliminate them from the manufacturing system, and then test how these changes affect the system. Do they make the system leaner or more wasteful?

Week #5: Production Planning and Scheduling

- Production planning, demand forecasting, resource allocation, linear programming, run time, and work scheduling.
- Lab: Students play interactive digital simulations, plan the production, allocate resources, and schedule workforces, to better meet customers' demands and if possible, maximize the profit.

Week #6: System Management with Adversity

- Comprehensive learning unit for students to apply their learned knowledge, skills, and tools.

- Lab: Students play interactive digital simulations, and manage and operate the manufacturing system under the influence of various stressful factors such as constant customer order changes, poor supply chain setup, unmotivated workforce, and high-pressure, fast-paced work environment.

Hub #3: Professional Skills in Manufacturing

Goal: Hub 3 focuses on developing technologists' competencies in non-technical professional skills. These skills help technologists lead, supervise, communicate, and work with other people, and better make decisions in ever-changing manufacturing work settings.

Learning Objectives:

- *Understand the impact of company policies on manufacturing production*
- *Use effective communication strategies in a manufacturing setting*
- *Lead and motivate others to work as a team*
- *Build a functional and high-performance team*
- *Adapt and react to pressures and adversities*

Week #1: Overview of Professional Skills in Manufacturing

- Management of workers in manufacturing.
- Introduce people skills as part of social capital management.

Week #2: Information and Infrastructure Management

- Infrastructure includes policy, incentives/evaluation systems, and physical setups.
- How incentive systems drive and impact manufacturing measures: quality, throughput.

Week #3: Effective Communication

- Clear and concise communication, both spoken and written, tailored to various audiences (colleagues, supervisors, and clients).
- Best practices for writing professional emails and reports.
- Active listening techniques that ensure understanding and effective collaboration.
- Lab to have students practice communication with others in different scenarios.

Week #4: General Management Skills

- Clearly defined roles and responsibilities (construct SMART goals and responsibility assignment matrices, e.g. RACI charts).
- Approaches and tools to track people's work progress.
- Lab to have students develop goals and RACI charts in Excel for given work tasks.

Week #5: Motivation and Leadership

- Leadership in manufacturing.
- Awareness and skills to motivate others at work.
- Lab to conduct script-guided role-playing activities, having students respond to workforces with different roles, work styles, and personalities.

Week #6: Team Building, Creating a Vision, and Establishing a Culture

- Team formation and team dynamics.
- Resolution of conflicts amicably and constructively.
- Creation of a clear vision for a team and ensuring buy-in.

Week #7: Adaptability to Changes in Manufacturing Environments

- How to adapt to changes in processes, technology, and organizational structures.
- Future manufacturing-oriented thinking using examples from Industry 4.0 and smart manufacturing.

Week #8: Making Decisions Under Pressure

- Effective time management and task prioritization.
- How to handle setbacks and remain productive in stressful environments.

Hub #4: Supply Chain in Manufacturing

Goal: Hub 4 strives to foster technologists' ability to handle inventory, plan resources, supervise logistics, and manage supply chains in manufacturing settings.

Learning Objectives:

- *Explain the importance and challenges of the supply chain*
- *Increase inventory usage and reduce holding costs*
- *Improve the procurement process*
- *Optimize logistics solutions in manufacturing settings*

Week #1: Introduction

- Importance of supply chain in manufacturing, supply chain complications, and why complex dynamic systems are difficult to navigate.
- Models for how suppliers, manufacturers, and distributors interact.

Week #2: Demand Forecasting and Planning

- Introduce Sales and Operations Planning (S&OP) to align production and inventory with demand forecasts, ensuring that supply meets demand while optimizing costs and resources.
- Techniques for predicting future customer demand using historical data and market analysis.

Week #3: Inventory Management

- Introduce inventory control concepts including just-in-time (JIT), safety stock, and reorder point strategies to balance inventory costs with service levels.
- Optimization of inventory levels across the supply chain, reducing excess inventory and avoiding stockouts.

Week #4: Procurement and Supplier Management

- Selection and evaluation of suppliers based on quality, cost, reliability, and sustainability, to ensure the supplier performance meets expectations.
- Supplier Relationship Management (SRM) to build and maintain strong relationships with suppliers to enhance collaboration, innovation, and risk management.

Week #5: Logistics and Distribution

- Transportation management plans and optimizes the movement of goods from suppliers to manufacturing facilities and from manufacturers to customers, which includes mode selection, route planning, and carrier management.
- Warehouse operation management which includes inventory storage, order picking, and shipping.

Week #6: Risk Management and Sustainability

- Supply Chain Risk Management which includes identifying and mitigating risks that could disrupt the supply chain.
- Awareness of building a sustainable supply chain to reduce the environmental impact of supply chain operations, including sustainable sourcing, green logistics, and waste reduction.

Spoke #1: Mechatronics

Goal: This spoke aims to bridge that gap and prepare learners for Industrial 4.0 manufacturing since technicians normally have a large knowledge gap with engineers in mechatronics.

Learning Objectives:

- *Describe the role and functionality of microcontrollers, embedded systems, and advanced sensors/actuators*
- *Evaluate and apply various communication protocols (e.g., UART, SPI, I2C, CAN, ZigBee, Bluetooth, Wi-Fi, TCP/IP)*
- *Integrate and troubleshoot complex mechatronic systems, applying control theories (e.g., PID) and advanced electronics*
- *Conduct research and utilize datasheets/manuals to identify and implement new sensors and actuators*
- *Apply system integration processes, including managing voltage levels and communication protocols*

Week #1: Introduction to Mechatronics

- Role of microcontrollers and embedded systems in mechatronics.
- Basic programming practices with LEDs and simple microcontrollers.

Week #2: Advanced Communication Protocols

- Mechanisms and differences of advanced communication protocols.
- Application of advanced communication protocols between sensors.

Week #3: Advanced Electronics

- Mechanisms and pros/cons of advanced sensors (optical flow sensors, encoders, IMUs, cameras) and actuators (smart servos). (Simulations available)
- Integration and programming of advanced components in a mechatronics system.

Week #4: Control Theories

- Understanding open/closed loop control and PID control.
- Applying closed-loop and PID control in sensor-actuator systems.

Week #5: Embedded Systems

- Role and functionality of embedded systems in automation.
- Programming and integration of embedded systems with sensors and actuators.

Week #6: System Integration

- Processes and challenges of integrating new equipment into existing systems.
- Implementing system integration with different voltages and communication protocols.

Week #7: Troubleshooting and Conclusion

- Role of DMAIC in debugging and troubleshooting.
- Assessing system performance and calibrating components in real-world scenarios.

Spoke #2: Automation Programming

Goal: This spoke aims to provide learners with a comprehensive understanding of control programming in manufacturing, bridging the gap between theoretical knowledge and practical applications to prepare them for Industry 4.0 environments.

High-Level Learning Objectives:

- *Describe the fundamentals of programming and its applications in industrial control systems*
- *Gain proficiency in PLC programming and its role in automation*
- *Learn the principles of CNC programming for precise control of manufacturing equipment*
- *Explore SCADA systems for real-time monitoring and control of manufacturing processes*
- *Describe Distributed Control Systems (DCS) and their application in complex industrial environments*
- *Learn about Manufacturing Execution Systems (MES) and their role in optimizing production processes*

Week #1: Fundamentals of Programming

- Introduction to programming languages used in industrial automation.
- Basic programming concepts and practices.

Week #2: PLC Programming

- Describe ladder logic, function block diagrams, and structured text.
- Developing and troubleshooting basic PLC programs.

Week #3: Advanced PLC Programming

- Integration of PLCs with sensors and actuators.
- Real-world applications and case studies.

Week #4: CNC Programming

- Apply G-code and M-code.
- Writing and simulating CNC programs for machining operations.

Week #5: Distributed Control Systems (DCS)

- Components and architecture of DCS.
- Designing and implementing control strategies using DCS.

Week #6: Embedded Systems

- Microcontroller programming and wiring.
- Sensor interfacing and data acquisition.

Week #7: Troubleshooting and Conclusion

- Debugging in general programming
- Debugging in manufacturing applications.

Spoke #3: Robotics

Goal: The goal of this spoke is to provide learners with a comprehensive understanding of robotics, from basic principles to advanced applications, enabling them to design, program, and implement robotic systems in various industrial settings.

High-Level Learning Objectives:

- *Describe the fundamentals of robotics, including kinematics, dynamics, and control*
- *Gain proficiency in programming robots using common frameworks and languages*
- *Gain knowledge in machine vision and its applications in robotics*
- *Develop skills in robot motion planning and navigation*
- *Explore the integration of robotics with machine learning and artificial intelligence*
- *Demonstrate the application of robotics in industry and research*

Week #1: Introduction to Robotics

- Overview of robotics concepts, history, and applications.
- Introduction to robot kinematics and dynamics, covering forward and inverse kinema and common user-end programming interface.

Week #2: Robot Programming Basics

- Introduction to common robot programming frameworks (e.g., ROS - Robot Operating System).
- Writing basic programs to control robot movements and actions.

Week #3: Motion Planning and Control

- Basics of robot motion planning, including path planning algorithms (e.g., A*, RRT).
- Implementing control strategies for robot motion.

Week #4: Machine Vision

- Fundamentals of machine vision and its role in robotics.
- Implementing vision-based systems for object detection, recognition, and tracking.

Week #5: Machine Vision with AI

- Integrating machine learning techniques with machine vision systems.
- Exploring AI algorithms for image processing, feature extraction, and decision-making in robotics.

Week #6: Machine Vision Integration in Robotics

- Practical applications of machine vision in robotic systems.
- Case studies on implementing vision-guided robots in various tasks such as assembly, inspection, and navigation.

Week #7: Industrial Applications and Resourcefulness

- Case studies of robotics applications in various industries (e.g., manufacturing, healthcare, logistics).
- Developing research skills and resourcefulness for continuous learning.

Spoke #4: 3D Modeling and Additive Manufacturing

Goal: This spoke aims to equip learners with the skills and knowledge required to create detailed 3D models and understand the principles and applications of additive manufacturing technologies.

High-Level Learning Objectives:

- *Master the fundamentals and advanced techniques of 3D modeling*
- *Gain proficiency in using 3D modeling software for complex designs*
- *Understand the principles and applications of additive manufacturing technologies*
- *Develop the ability to design for and optimize additive manufacturing processes*
- *Acquire skills in post-processing and improving the quality of 3D printed parts*
- *Explore cutting-edge trends and innovations in the field*

Week #1: Introduction to 3D Modeling and Basic Techniques

- Overview of 3D modeling concepts, design principles, and popular software.
- Creating and manipulating basic shapes, understanding geometric transformations, and applying simple textures and materials.

Week #2: Advanced 3D Modeling Techniques

- Working with complex surfaces and meshes, creating intricate structures.
- Advanced texturing, material applications, and introduction to parametric modeling.

Week #3: Introduction to Additive Manufacturing

- Overview of additive manufacturing technologies (FDM, SLA, SLS), understanding the workflow from 3D model to print.
- Basics of setting up 3D printers, understanding slicing software, and preparing models.

Week #4: Design for Additive Manufacturing (DfAM)

- Principles of designing for additive manufacturing, optimizing designs for different technologies.
- Techniques for minimizing support structures, improving printability, and enhancing structural integrity.

Week #5: Post-Processing Techniques

- Components and architecture of DCS.
- Designing and implementing control strategies using DCS.

Week #6: Advanced Additive Manufacturing Applications

- Exploring advanced materials (composites, metals, bio-materials) and their applications.
- Case studies of additive manufacturing in aerospace, healthcare, and automotive industries.

Week #7: Future Trends and Innovations in Additive Manufacturing

- Investigating emerging technologies (multi-material printing, hybrid manufacturing) and novel materials.
- Exploring the future impact of additive manufacturing.

Spoke #5: Machining

Goal: The goal of this spoke is to provide learners with a comprehensive understanding of machining principles and practices, enabling them to operate, program, and maintain machining equipment in an industrial setting.

High-Level Learning Objectives:

- Describe the fundamentals of machining and different machining processes.
- Gain proficiency in using and programming CNC machines.
- Learn about tooling, material properties, and machining parameters.
- Explore advanced machining techniques and technologies.
- Perform maintenance and troubleshooting of machining equipment.
- Illustrate the importance of machining dynamics.

Week #1: Introduction to Manufacturing and Tools

- Overview of machining concepts, history, and applications.
- Introduction to different machining processes (e.g., turning, milling, drilling).

Week #2: Manufacturing CNC Principles

- Demonstrate the operator checklist for safety and machine operations.
- Provide an the introduction to chip formation,forced and free vibrations and tooling and possible wear effects

Week #3: Manufacturing CNC Principles

- Provide an introduction to turning and milling details and G-Code.
- Introduction to measurements

Week #4: Machine Dynamics

- Introduction to tool and workpiece flexibility, cutting force, vibration, and chattering.
- Basics of vibration and frequency response functions.

Week #5: Machine Dynamics and Additive Manufacturing

- Considerations regarding chattering, tool wear, and damping.
- Introduction to additive manufacturing, materials, and benefits.

Week #6: Machine Costs and Tolerances

- Estimate the impact of tools and materials on budget estimation.
- Assess the process of providing information required to manufacture a part.

Week #7: CAM+ and Advanced Topics

- Explore the usage of software in tooling and machining.

Spoke #6: Digital Manufacturing

Goal: The goal of this spoke is to equip learners with the knowledge and skills to implement digital manufacturing technologies, including simulation, digital twins, and advanced data analytics, to enhance manufacturing processes and decision-making.

High-Level Learning Objectives:

- *Describe the fundamentals of digital manufacturing and its impact on modern industry*
- *Gain proficiency in using simulation tools for process optimization*
- *Learn about digital twins and their applications in manufacturing*
- *Develop skills in advanced data analytics and their use in manufacturing*
- *Explore the integration of digital technologies to improve efficiency and productivity*
- *Describe the role of digital manufacturing in Industry 4.0 and future trends*

Week #1: Introduction to Digital Manufacturing

- Overview of digital manufacturing concepts, Industry 4.0, and its impact.
- Introduction to basic digital tools and platforms used in manufacturing.

Week #2: Simulation in Manufacturing

- Simulation basics and its importance in manufacturing with hands-on practice using simulation software.
- Building simple simulation models for process optimization.

Week #3: Advanced Simulation Techniques

- Exploring advanced simulation techniques (discrete event simulation, finite element analysis).
- Practical examples and case studies of simulation applications in manufacturing.

Week #4: Digital Twins

- Introduction to digital twins, creating digital twins for real-time monitoring.
- Practical implementation of digital twins using popular software.

Week #5: Advanced Data Analytics

- Basics of data analytics, techniques for collecting and analyzing manufacturing data.
- Hands-on projects using tools like Python and Tableau for data analysis in manufacturing.

Week #6: Integration of Digital Technologies

- Integrating simulation, digital twins, and data analytics in manufacturing processes with case studies.
- Strategies for managing digital transformation in manufacturing environments.

Week #7: Future Trends and Continuous Learning

- Exploring future trends in digital manufacturing and emerging technologies.
- Techniques for effective online research, leveraging professional networks, and developing self-motivated learning strategies.

Spoke #7: Microelectronic Assembly

Goal: The goal of this spoke is to equip learners with the knowledge and skills required for microelectronic assembly, including handling microelectronic components, precise soldering techniques, and quality assurance practices, preparing them for work in advanced electronics manufacturing.

High-Level Learning Objectives:

- *Describe the fundamentals of microelectronic packaging and assembly technologies*
- *Gain proficiency in various microelectronic assembly techniques*
- *Learn about advanced packaging methods like Flip Chip and Multichip Modules (MCM)*
- *Develop skills in quality assurance and materials qualification*
- *Describe the importance of industry standards such as ISO 9001:2008*

Week #1: Introduction to Electrical Components

- Overview of semiconductor packaging methods and their importance in microelectronics.
- Understanding Chip & Wire Technology and its applications in microelectronic assemblies.

Week #2: Flip Chip Attachment and Mixed Assembly Technology

- Basics of Flip Chip Attachment and its advantages in microelectronic packaging.
- Explore Mixed Assembly Technology, combining different packaging techniques for complex assemblies.

Week #3: Multichip Modules (MCM) and Package-on-Package (PoP)

- Introduction to Multichip Modules (MCM) and their role in high-density electronic assemblies.
- Understanding Package-on-Package (PoP) technology for stacking multiple chips.

Week #4: System-in-Package (SiP) and Advanced Assembly Techniques

- Overview of System-in-Package (SiP) technology and its integration capabilities.
- Advanced assembly techniques for SiP and other high-precision microelectronic components.

Week #5: Materials Qualification and Quality Assurance

- Understanding the importance of materials qualification in microelectronic assemblies.
- Techniques for ensuring material quality and reliability in electronic packaging.

Week #6: ISO 9001:2008 Certification and Industry Standards

- Overview of ISO 9001:2008 certification and its relevance to microelectronic manufacturing.
- Implementing industry standards and best practices in microelectronic assembly processes.

Week #7: Troubleshooting, Maintenance, and Future Trends

- Common issues in microelectronic assemblies and effective troubleshooting techniques.
- Best practices for maintaining microelectronic systems and exploring future trends in the industry.

Spoke #8: Electrical Assembly

Goal: The goal of this spoke course is to provide learners with a basic understanding of electrical assembly, including the fundamentals of electrical components, wiring, and system integration, preparing them for practical application in various industrial settings.

High-Level Learning Objectives:

- Apply the basics of electrical components and their functions.
- Read and interpret electrical schematics, symbols, and diagrams.
- Demonstrate proper techniques for wiring and soldering.
- Demonstrate skills in assembling and testing electrical circuits and systems.
- Apply safety practices and standards in electrical assembly.
- Troubleshoot and maintain electrical systems effectively.

Week #1: Introduction to Electrical Components
- Overview of basic electrical components (resistors, capacitors, inductors, diodes, transistors).
- Describe the functions and specifications of these components.

Week #2: Reading Electrical Schematics
- Basics of electrical schematics, symbols, and diagrams.
- Practice reading and interpreting simple to complex electrical schematics.

Week #3: Wiring and Soldering Techniques
- Proper techniques for wiring and cable management (including connectors, cable harness, shielding and grounding).
- Introduction to IPC standards for soldering and electronic assembly.
- Hands-on practice in soldering components.

Week #4: Assembling Electrical Circuits
- Step-by-step assembly of basic electrical circuits.
- Testing and troubleshooting assembled circuits to ensure functionality with proper tools.

Week #5: System Integration
- Integrating multiple electrical circuits into a cohesive system.
- Implementing system-level wiring and connections.
- Implementing wire labeling and documentation.

Week #6: Safety Practices and Standards
- Overview of safety practices in electrical assembly.
- Overview of Electrostatic Discharge (ESD) precautions and procedures.
- Overview of IP rating.
- Describe industry standards and regulations for electrical systems.

Week #7: Troubleshooting and Maintenance
- Common issues in electrical assemblies and troubleshooting techniques.
- Best practices for maintaining and servicing electrical systems.