Smart Manufacturing Education and Training Modules

July 2021

Hi-TEC 2021

CESMII
THE SMART MANUFACTURING INSTITUTE

July 2021
Smart Manufacturing
Education and Training Modules

Conrad Leiva
Director of Ecosystem and Workforce Education at CESMII
conrad.leiva@cesmii.org

Sam Samanta
Smart Systems Technologies, Finger Lakes Community College
sam.samanta@flcc.edu
AGENDA

• Upskilling the Workforce with Smart Manufacturing Skills
  • CESMII has a roadmap for training the workforce. We present outlines of learning modules with the goal of recruiting more community colleges to our endeavor.

• Examples of SM Strategies, Technologies, and Solutions
  • SM Concepts and Principles
  • The Relation between Technology, Solutions and Strategies
  • Data Sources, Information modeling, Visualization
  • Data Analysis, Process and Resource Optimization, Troubleshooting
  • Edge, Cloud, Digital Twin, Cyber Security
  • Connected Worker, Orchestrated Operations, Digital Supply Chain

• Join us in this effort
Transitioning Industry 3.0 to Industry 4.0 techniques

“Industry 2.5”
Digitization
Digitize and organize information. Move from paper to digital documents and spreadsheets.

“Industry 3.0”
Digitalization
Automate and streamline processes using digital OT and IT technologies.
Implementation of PLCs, NC, CAD, CAM, CMM, ERP, MES, PLM.

“Industry 4.0”
Digital Transformation
Highly integrated people, process and technology in digitally-enabled operating models and business processes.
Implementation of Smart Manufacturing, interoperable cyber-physical systems, OT-IT convergence, information models, digital thread, digital twins, AI, cobots, mobile, data lakes, edge and cloud computing.

sam.samanta@flcc.edu  conrad.leiva@cesmii.org
Challenges to achieving Industry 4.0 techniques

<table>
<thead>
<tr>
<th>Technology? No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensor</strong></td>
</tr>
<tr>
<td><strong>Data</strong></td>
</tr>
<tr>
<td><strong>Device</strong></td>
</tr>
<tr>
<td><strong>Connectivity</strong></td>
</tr>
</tbody>
</table>

**Talent, Interoperability**

Q: What are your company’s top operational challenges in meeting its strategic objectives?

<table>
<thead>
<tr>
<th>Challenge</th>
<th>% Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talent/skills shortage</td>
<td>35</td>
</tr>
<tr>
<td>Disparate systems and data sources</td>
<td>27</td>
</tr>
<tr>
<td>Timely visibility to performance metrics</td>
<td>27</td>
</tr>
<tr>
<td>ROI justification for investment</td>
<td>24</td>
</tr>
<tr>
<td>Reduced budgets</td>
<td>24</td>
</tr>
<tr>
<td>Lack of continuous improvement process</td>
<td>20</td>
</tr>
<tr>
<td>Lack of cross-functional collaboration</td>
<td>20</td>
</tr>
<tr>
<td>Lack of executive support</td>
<td>6</td>
</tr>
</tbody>
</table>
Workforce Skills have not been keeping up
Manufacturers need Talent that knows how to implement SM Technologies, Solutions and Strategies

- Smart Machines
- Process Modeling
- Wearables
- Sensor
- PLC
- Microcontrollers
- Microcontrollers
- Actuators
- Data Visualization
- Big Data
- Machine Vision
- GPU
- FPGA
- Artificial Intelligence
- Root Cause Analysis
- Predictive Analysis
- Enterprise Systems
- Business Continuity
- Troubleshooting
- Connected Worker
- Orchestration Operations
- Digital Supply Chain
- Business Continuity
- Industrial Cyber Security
- Continuous Improvement
- Process Modeling

Contact:
- sam.samanta@flcc.edu
- conrad.leiva@cesmii.org
## Smart Manufacturing Skills for the Workforce

### Manufacturing Roles to Upskill

<table>
<thead>
<tr>
<th>Role/Staff</th>
<th>Plant/Operations/Maintenance/Staff, Workers</th>
<th>Continuous Improvement Engineer</th>
<th>Predictive Analysis Modeler, Process Engineer</th>
<th>Manufacturing Data Analyst, Report Dev Staff</th>
<th>SM Solution Implementor, System Integrator</th>
<th>SM Information Model Manager, Data Profile Developer</th>
<th>Manufacturing System Designers and Architects</th>
<th>Manufacturing Business Leaders, Innovation Champions</th>
</tr>
</thead>
</table>
Smart Manufacturing is...

Smart manufacturing is the information-driven, event-driven, efficient, and collaborative orchestration of business, physical and digital processes within plants, factories, and across the entire value chain.

In Smart Manufacturing, resources and processes are integrated, monitored, and continuously evaluated with the sensing, information, process modeling, predictive analytics, and workflows needed to automate routine actions and prescribe actions for non-routine situations.

In Smart Manufacturing, organizations, people, and technology work in synergy via business and manufacturing processes and technology-based solutions that strive to be:

- secure,
- scalable,
- flat and real-time,
- open and interoperable,
- proactive and semi-autonomous,
- orchestrated and resilient, and
- sustainable and energy efficient.

Smart Manufacturing is transformational, radically impacting the performance of the manufacturing ecosystem through measurable improvements in cost/profitability, asset reliability, quality, energy productivity-and more strategically in areas such as speed, agility/resiliency, innovation, partnering opportunities.


sam.samanta@flcc.edu    conrad.leiva@cesmii.org
Data Sources
Sensors, Actuators, Inputs/Outputs

• Sensors help measure/monitor parameters of interest, such as Temperature, Pressure, Linear and Rotational Position, Accelerometers, Proximity etc. More complex sensors include Machine Vision, and others that identify Chemicals & Biologics. (Smart Phones have 6+ sensors)

• Actuators are typically electromechanical systems that respond to electrical signals – include solenoids and robots.

• Inputs are typically electrical voltages and current signals from sensors

• Outputs are voltages that drive actuators, or control sensor parameters

Aachen University PhyPhox App Collect data & email as an Excel file
Automation Controllers: CPU, μP, mC, PLC, FPGA, GPU

• Microprocessor μP CPU+Memory+ ADC+DAC => Microcontrollers (μC, e.g. Arduino)

• Programmable Logic Controller (PLC) are used across industries (e.g. Rockwell Automation and Siemens)

• Field Programmable Gate Arrays (FPGA) software create “custom logic chip” during R&D, cheaper than ASIC

• GPU: Accelerate graphics calculations (NVIDIA’s Jetson Nano (<$100) has quadcore ARM CPU and 128 GPUs, useful for Machine Vision, IIoT, AI, Edge & Cloud Computing)
Big Data, Predictive Analysis & Maintenance

• Big Analog Data: Vibration sensors (accelerometers) generate vast amount of data => must be analyzed in real-time to extract actionable intelligence, instead of simply storing the data.

• Big Digital Data: Multi-terabyte of data are collected by vision & other systems help improve processes (Accelerated Machine Learning: Data from Tesla cars help improve object identification algorithms, that quickly make all Tesla cars smarter through SW updates. )

• Machine Learning / AI can help forecast brewing potential problems (i.e. using vibration sensor data), and trigger alarms for predictive maintenance
Cloud & Edge Computing

• Cloud Computing is basically computing on remote servers with mirrored sites to provide uninterrupted computing as a service. Examples include remote SQL, databases, cloud-based image recognition, and pattern detection in other sensor data streamed to the cloud. Zoom, WebEx are cloud services. Cloud computing can provide remote control of industrial systems if latent-time delays can be tolerated.

• Edge computing, computing co-located with the source of big analog/digital data (accelerometers, machine vision) to extract intelligence in real-time for immediate action, without always having the need to store/transfer big data.

• NVIDIA Jetson Nano costing less than $100 is a good teaching tool/platform for Edge Computing and Cloud Computing.
Data Visualization

Basic Skills:
• Plotting and Interpreting Data Graphs
• Human Machine Interfaces (HMI)

Advanced Concepts & Skills
• Data visualization facilitates right-brain approach to “detecting patterns” in large table of numbers or text-based description of the data sets
• Data visualization is increasingly used for interacting with control algorithms and machines, especially for extracting insights from big data
• Augmented Virtual Reality (AVR) is based on Spatial Computing which aids visualization and manipulation of 3d-simulated entities that interact with real surroundings (MagicLeap, HoloLens 2)

Connected Augmented Worker

**Team Collaboration**
Every worker as good as the best worker

**IIOT data available in the field**
Access to information in the right place at the right time, directly from automation system

**Work Guidance**
Step-by-step instructions, diagrams and knowledge base

**Remote Assist**
Video collaboration, hands-free, in the field, back to an expert or across the plant

Industrial Cyber Security

Cyber Security Framework

https://www.cesmii.org/cybersecurity-in-manufacturing/
Smart, Sustainable Manufacturing and Energy Efficiency

Platform connects manufacturers and supply chain partners to leverage real-time data sources to monitor performance, auto-detect unusual patterns and trigger action.

Industry and value chain standards are defined to facilitate ecosystem interaction and data exchange.

Collaborative innovation among partners in the ecosystem for improved circular product lifecycle and product-as-a-service.

Integrated regulatory stakeholders for direct compliance data transfers.

Process optimization and visibility dashboards for operations and supply chain KPIs and risk factors.

Parts and material traceability information is integrated among partners and suppliers in the value chain.

Energy managed as direct ingredient instead of treated as overhead cost.

Energy usage scheduled based on lower-cost times provided by Smart Grid data.

Inventory minimized with on-demand scheduling hub to manage parts and material across suppliers in response to changes in demand or capacity.

Dark warehouses are highly automated, energy efficient, reduce waste due to material handling errors.

Logistics optimized and transportation cost reduced.

Compliance monitoring system and supplier auditing capabilities.
Process Modeling and Optimization

• First principles process modeling involves differential equations, which could be converted to difference equations to introduce students to numerical methods using Excel, LabVIEW, and FEA programs, among other special purpose software.

• Chemicals, food or pharmaceuticals can be batch-processed, or through continuous process.

• Empirical models are useful in many cases for their simplicity and cost savings.

• Digital Twins are based on detailed process and system modeling.
Digital Twins

A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity.

• Digital twin use real-time and historical data to represent the past and present and simulate predicted futures.

• Digital twins are motivated by outcomes, tailored to use cases, powered by integration, built on data, guided by domain knowledge, and implementation in IT/OT systems.
Artificial Intelligence (AI) and Machine Learning (ML)

AI is used for automating information processing for extracting actionable insights, typically in known context.
# Quality Improvement & Root Cause Analysis

Data-driven analysis, problem solving, and decision-making needs the right data context to relate problems to resources: equipment, tools, personnel, etc.

<table>
<thead>
<tr>
<th><strong>Define</strong></th>
<th><strong>Measure</strong></th>
<th><strong>Analyze</strong></th>
<th><strong>Improve</strong></th>
<th><strong>Control</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Voice of Customer</td>
<td>• Data Collection</td>
<td>• Pareto Charts</td>
<td>• Design of Experiments</td>
<td>• Machine Control</td>
</tr>
<tr>
<td>• Risk Assessment</td>
<td>• Process Capability</td>
<td>• Fishbone Diagram</td>
<td>• What-If Analysis</td>
<td>• Statistical Process Control</td>
</tr>
<tr>
<td>• Affinity Diagram</td>
<td>• Metrics, KPIs</td>
<td>• Scatter Diagram</td>
<td>• CAPA</td>
<td>• Process Workflow</td>
</tr>
<tr>
<td>• Kano Model</td>
<td>• Defects, Scrap</td>
<td>• ANOVA</td>
<td></td>
<td>• Work Instruction</td>
</tr>
</tbody>
</table>

Smart Manufacturing DATA and INSIGHTS
Digital Supply Network

The Smart Factory is a node in Smart Supply Chain
Digital Supply Network

A connected supply chain is more resilient to maintaining business continuity

<table>
<thead>
<tr>
<th>Anticipation</th>
<th>Resistance</th>
<th>Response / Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visibility</strong></td>
<td><strong>Redundancy</strong></td>
<td><strong>Velocity</strong></td>
</tr>
<tr>
<td><strong>Awareness</strong></td>
<td><strong>Collaboration</strong></td>
<td><strong>Adaptability</strong></td>
</tr>
<tr>
<td>Demand forecast change anticipation triggers.</td>
<td>Collaborative culture with suppliers and partners to adapt to changes.</td>
<td>Ability to change product rate, configuration, and mix.</td>
</tr>
<tr>
<td><strong>Supplier Communication</strong></td>
<td><strong>Market Position</strong></td>
<td><strong>Supplier Relations</strong></td>
</tr>
</tbody>
</table>
Collaborative Ecosystem of 140+ Members

<table>
<thead>
<tr>
<th>ACEEE</th>
<th>AEROSPACE</th>
<th>ARCONIC</th>
<th>ATOLGY</th>
<th>EMERSON</th>
<th>RES Group Inc.</th>
<th>Sentience</th>
<th>Savigent</th>
<th>Fluence Analytics</th>
<th>SAINT-GOBAIN</th>
<th>ENEO</th>
<th>Avid</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUBURN</td>
<td>Autodesk</td>
<td>CMTC</td>
<td>CSUN</td>
<td>GE</td>
<td>SyncFab</td>
<td>Syracuse University</td>
<td>ISIS</td>
<td>SDSC</td>
<td>CCAM</td>
<td>OptiPro</td>
<td>TECHNOLOGY SOLUTIONS</td>
</tr>
<tr>
<td>UTEP</td>
<td>Digitronik Labs</td>
<td>@El Camino College</td>
<td>ThinkIQ</td>
<td>FingerLakes</td>
<td>Berkeley</td>
<td>RAYONIER Advanced Materials</td>
<td>Moldex3D</td>
<td>Earth Resource</td>
<td>University of Virginia</td>
<td>UNIVERSITY OF VIRGINIA</td>
<td></td>
</tr>
<tr>
<td>General Mills</td>
<td>Groundswell</td>
<td>Honeywell</td>
<td>IDENTify3D</td>
<td>UCI</td>
<td>CALIT2</td>
<td>UCLA</td>
<td>UCONN</td>
<td>University of Louisville</td>
<td>University of New Hampshire</td>
<td>Oregon State University</td>
<td>Northeastern University</td>
</tr>
<tr>
<td>IFS INDUSTRY</td>
<td>AMQP</td>
<td>JOHNSON &amp; JOHNSON</td>
<td>LAMAR UNIVERSITY</td>
<td>IFS Industry</td>
<td>Automation</td>
<td>UCDAM</td>
<td>TEXAS</td>
<td>University of Tennessee</td>
<td>Virginia Tech</td>
<td>RIT</td>
<td></td>
</tr>
<tr>
<td>TULIP</td>
<td>LSU</td>
<td>MORF3D</td>
<td>INFOLIGIC</td>
<td>VISTEX</td>
<td>WPI</td>
<td>aspentech</td>
<td>RUTGERS</td>
<td>3G</td>
<td>MIT</td>
<td>RIT</td>
<td></td>
</tr>
<tr>
<td>NSD</td>
<td>NC STATE UNIVERSITY</td>
<td>PennState</td>
<td>SME</td>
<td>ITAMCO</td>
<td>Northwest</td>
<td>Tokyo Community College</td>
<td>University of Tennessee</td>
<td>Cincinnati</td>
<td>MESA</td>
<td>MathWorks</td>
<td></td>
</tr>
<tr>
<td>Praxair</td>
<td>Raytheon</td>
<td>Rensselaer</td>
<td>Microsoft</td>
<td>ExxonMobil</td>
<td>Global Technologies Research Center</td>
<td>University of Houston</td>
<td>Conagra</td>
<td>Concordia</td>
<td>Michigan Technological University</td>
<td>The University of Texas Rio Grande Valley</td>
<td>Conrad</td>
</tr>
</tbody>
</table>

25
Join us in this journey!

Visit www.cesmii.org for more info.

CESMII also has an open Request for Proposals at: https://www.cesmii.org/resources-rfp3/

Conrad Leiva
Dir Ecosystem and Workforce Education
conrad.leiva@cesmii.org

Sam Samanta
Professor at Finger Lakes Community College
sam.samanta@flcc.edu
Thank you

Democratizing **Smart Manufacturing**

- Educated, Digital Culture
- Connected Smart Assets
- Information-Driven Decisions
- Operations & Supply Chain Agility

conrad.leiva@cesmii.org

www.cesmii.org