Cyber-Physical Systems Undergraduate Education

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There is a major need for standard curriculum guidance for cyber-physical systems (CPS) education. CPS courses should be deeply intertwined with hands-on training on real world hardware such as industrial control systems (ICS). These courses should be accessible to a broad range of engineering students and establish a framework for a CPS education grounded in engineering principles, theory, and interactive, hardware-based labs.

What is CPS?

- Sensors & Controllers Reacting to Physical Inputs and Communicating over a Network to Achieve Intended Effects

Why CPS?

- Awareness & Knowledge
- Intertwined in Critical Infrastructure
- Engineer's Role in the Future of CPS

Students in CPS Today

- Education is Diverse but Not Common
- Minimal Hands-On Training
- Learning Varies Across Institutions

Literature on CPS Education

- Two Common Themes

1. Broader Availability of CPS Engineers
2. Baseline of Core Concepts for CPS Education
    1. Basic Computing
    2. Discrete & Continuous Mathematics
    3. Interfacing with the Physical World
    4. Sensors & Actuators
    5. Communications & Networking
    6. Modeling & Controls
    7. Embedded Systems
    8. Real-Time & Continuous Systems
    9. Development & Verification of CPS Models

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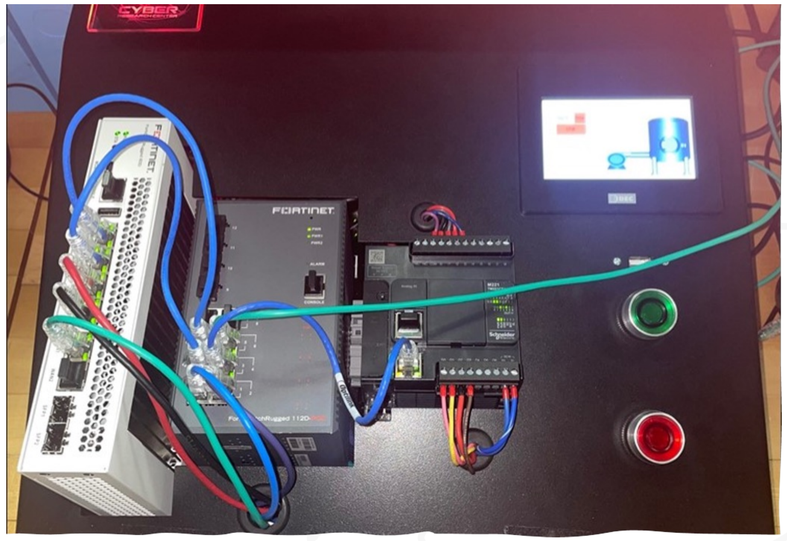
Example Lab Bench with Real Equipment



Benchmarking CPS Curricula

Course/Textbook	DePaul	UAlbany	Nebraska-Lincoln	UC, Berkeley	UC, Santa Cruz	UHouston	Carnegie Mellon	EvCC
I/O	■	■	■	■	■	■	■	■
Sensors	■	■		■	■	■	■	■
Actuators	■	■		■	■	■	■	■
Control	■	■	■	■	■	■	■	■
Discrete Aspects	■	■	■	■	■			
Raspberry Pi	■	■						
Automata		■	■	■	■		■	■
Scheduling	■	■		■	■			■
Security	■	■		■				■
Networking	■	■				■		■
ADC/DAC	■	■	■	■	■			
Concurrency		■		■	■			■
State Machines		■	■	■	■			
Introduction to Embedded Systems: A Cyber-Physical Systems Approach, 2nd ed. By Lee & Seshia, MIT Press		■	■	■	■			
Principles of Cyber-Physical Systems by Rajeev Alur, MIT Press	■	■	■					
Exploring Raspberry Pi: Interfacing to the Real World with Embedded Linux by Derek Molloy, Wiley		■						
Logical Foundations of Cyber-Physical Systems by André Platzer, Springer	■						■	

Key Takeaways for CPS Education

- Fractured Nature of CPS Education
- Heavy Academic and Industry Attention Necessary
- Soft Skills Should be Focused on in Academia
- Prerequisites Low for Interdisciplinary Reach
- Hands-On Training is Necessary
    - Crawl, Walk, Run Method
    1. Familiarity with CPS and Programming
    2. Manipulation and Analysis of CPS Network
    3. Implementation of Purdue Reference Model on Local CPS

References

Albert M. K. Cheng. 2014. An undergraduate cyber-physical systems course. In Proceedings of the 4th ACM SIGBED International Workshop on Design, Modeling, and Evaluation of Cyber-Physical Systems (CyPhy '14). Association for Computing Machinery, New York, NY, USA, 31–34. https://doi.org/10.1145/2593458.2593464
Isuru Godage. [n. d.]. CSE 331: Cyber-Physical Systems Engineering I. DePaul University, College of Computing and Digital Media ([n. d.]).
Isuru Godage. 2020. CSE 332: Cyber-Physical Systems Engineering II. DePaul University, College of Computing and Digital Media (2020).
[Isuru Godage. 2020. CSE 333: Cyber-Physical Systems Engineering III. DePaul University, College of Computing and Digital Media (2020).
Joint Task Force on Cybersecurity Education. 2017. Cybersecurity Curricula 2017: Curriculum Guidelines for Post-Secondary Degree Programs in Cybersecurity. Technical Report. ACM, IEEE-CS, AIS SIGSEC, and IFIP WG 11.8. https://doi. org/10.1145/3184594
Edward A. Lee. 2016. EECS 149/C249A: Introduction to Embedded Systems. University at Albany, State University of New York (2016).
Elena Mäkiö-Marusik. 2017. Current Trends in Teaching Cyber Physical Systems Engineering: A Literature Review. In 2017 IEEE 15th International Conference on Industrial Informatics (INDIN). IEEE, 518–525. https://doi.org/10.1109/INDIN. 2017.8104826
Peter Marwedel, Tulika Mitra, Martin Edin Grimheden, and Hugo A. Andrade. 2020. Survey on Education for Cyber-Physical Systems. IEEE Design & Test 37, 6 (Dec. 2020), 56–70. https://doi.org/10.1109/MDAT.2020.3009613
National Academies of Sciences, Engineering, and Medicine. 2016. A 21st Century Cyber-Physical Systems Education. The National Academies Press, Washington, DC. https://doi.org/10.17226/23686
Sharief Oteafy. 2020. TDC 390 / CSE 314 Syllabus - Networking for IoT. DePaul University, College of Computing and Digital Media (2020).
Dola Saha. 2020. IECE 553/453: Cyber-Physical Systems. University at Albany, State University of New York (2020).
Ricardo G. Sanfelice. 2014. CMPE142 - Introduction to Cyber-physical Systems. University of California, Santa Cruz, Department of Computer Engineering (2014).
Filipo Sharevski. [n. d.]. CSE316/426 - Cyber Physical Systems Security Syllabus. DePaul University, College of Computing and Digital Media ([n. d.]).
John A Stankovic, James W Sturges, and Jon Eisenberg. 2017. A 21st century cyber-physical systems education. Computer 50, 12 (2017), 82–85. https://doi. org/10.1109/MC.2017.4451222