Presentation to the National Academies' Committee on "Infusing Advanced Manufacturing in Engineering Education" Re: Lessons from Mfg. Institutes Study

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Co-Chair, NAS NMMB Study on "DOD Engagement with its Manufacturing Innovation Institutes," October 2021

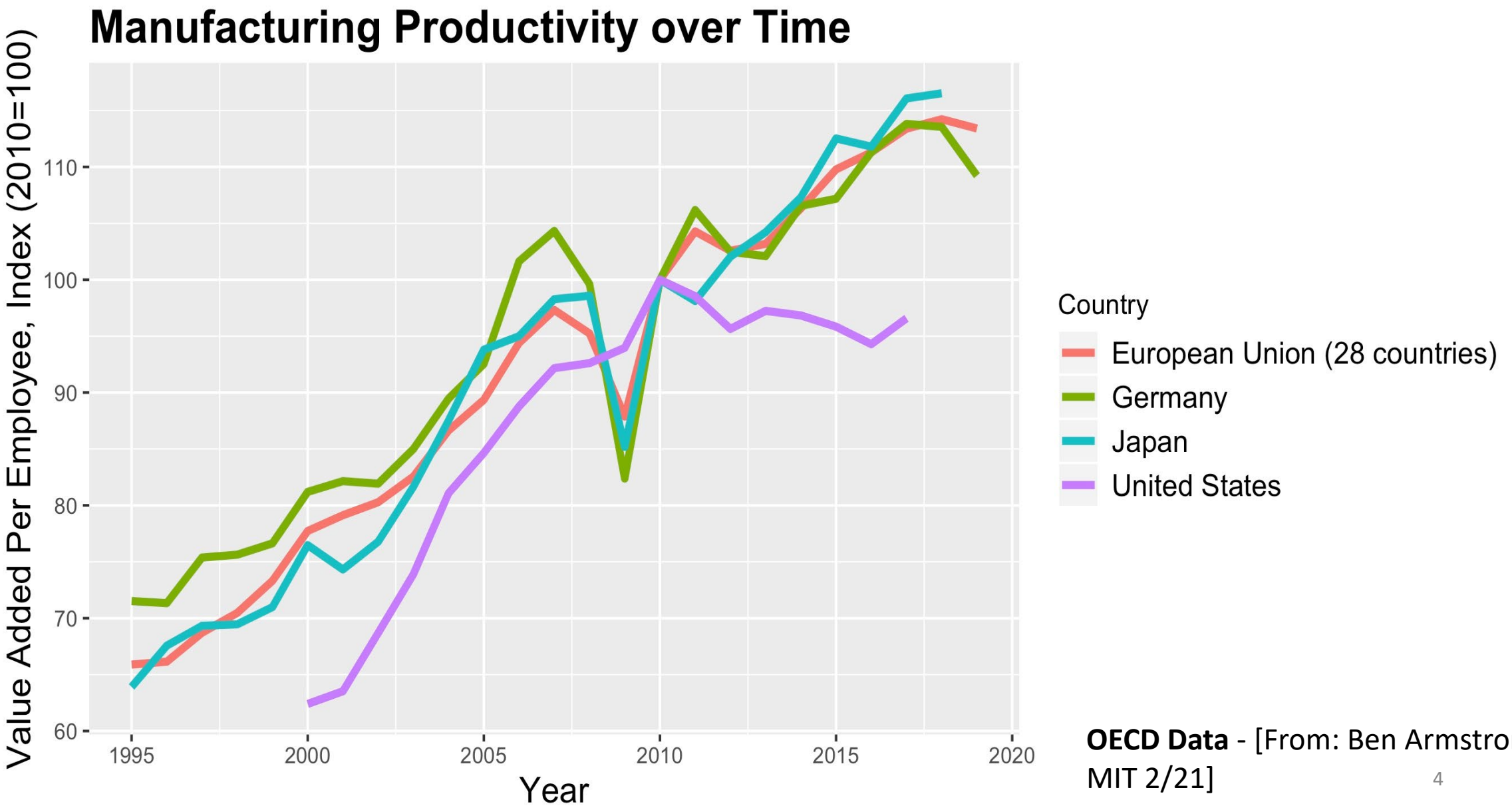
October 27, 2021

Introduction -

- Written extensively on Advanced Manufacturing and Workforce Education
  - William B. Bonvillian and Peter L. Singer, *Advanced Manufacturing – the New American Innovation Policies* (MIT Press 2018)
  - William B. Bonvillian and Sanjay Sarma, *Workforce Education, A New Roadmap* (MIT Press 2021)
- Co-chaired the recent NAS NMMB report on "DOD Engagement with its Manufacturing Innovation Institutes" (Oct. 2021)
- Bob Sproull asked me to review key findings from the recent NAS report – which focused more on the technical workforce, not engineering – and some of the work I have been undertaking on workforce education

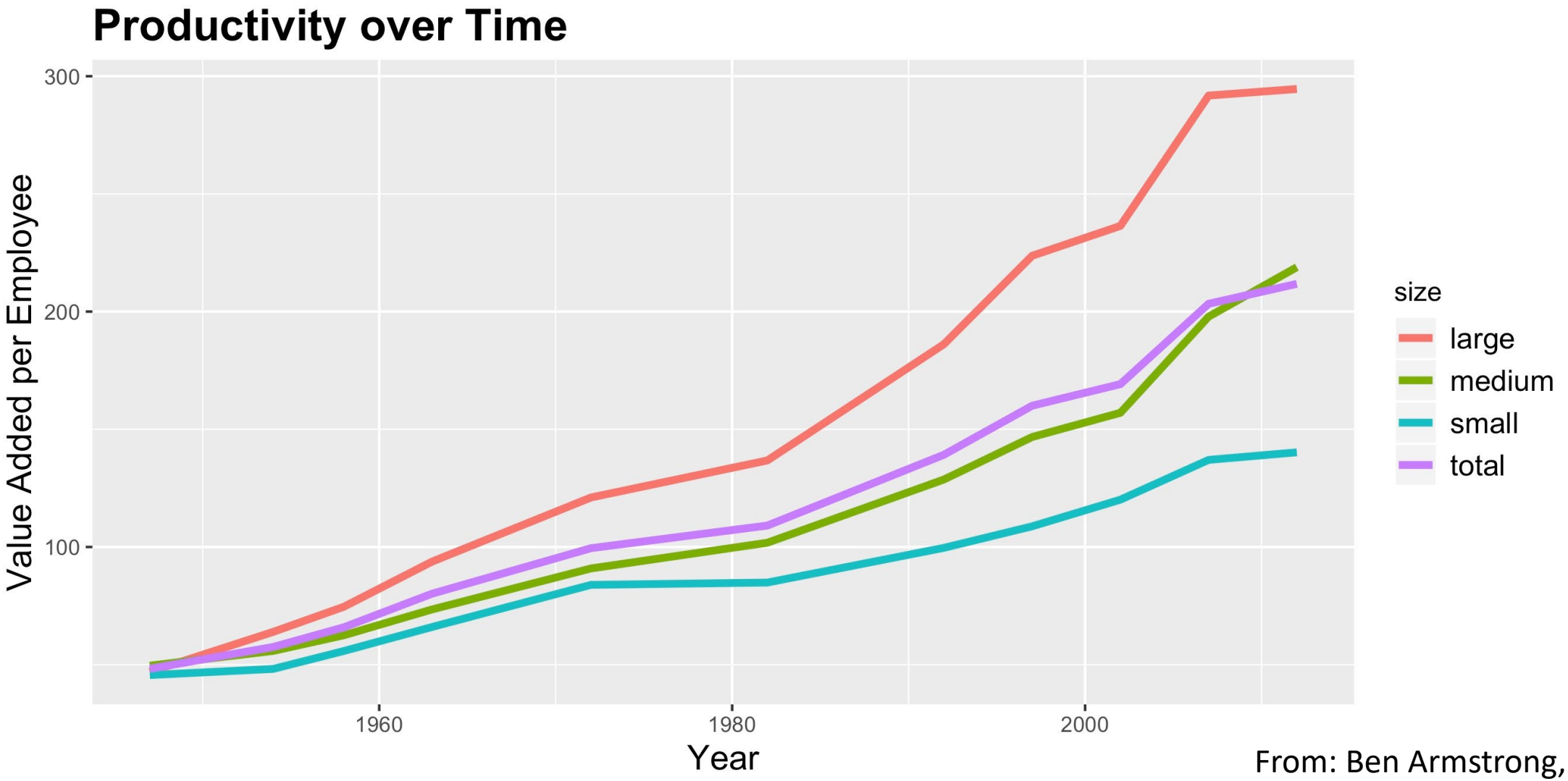
Quick Background on Advanced Manufacturing Issues our Committee Saw

US Manufacturing Productivity Lags Behind Competitor Nations



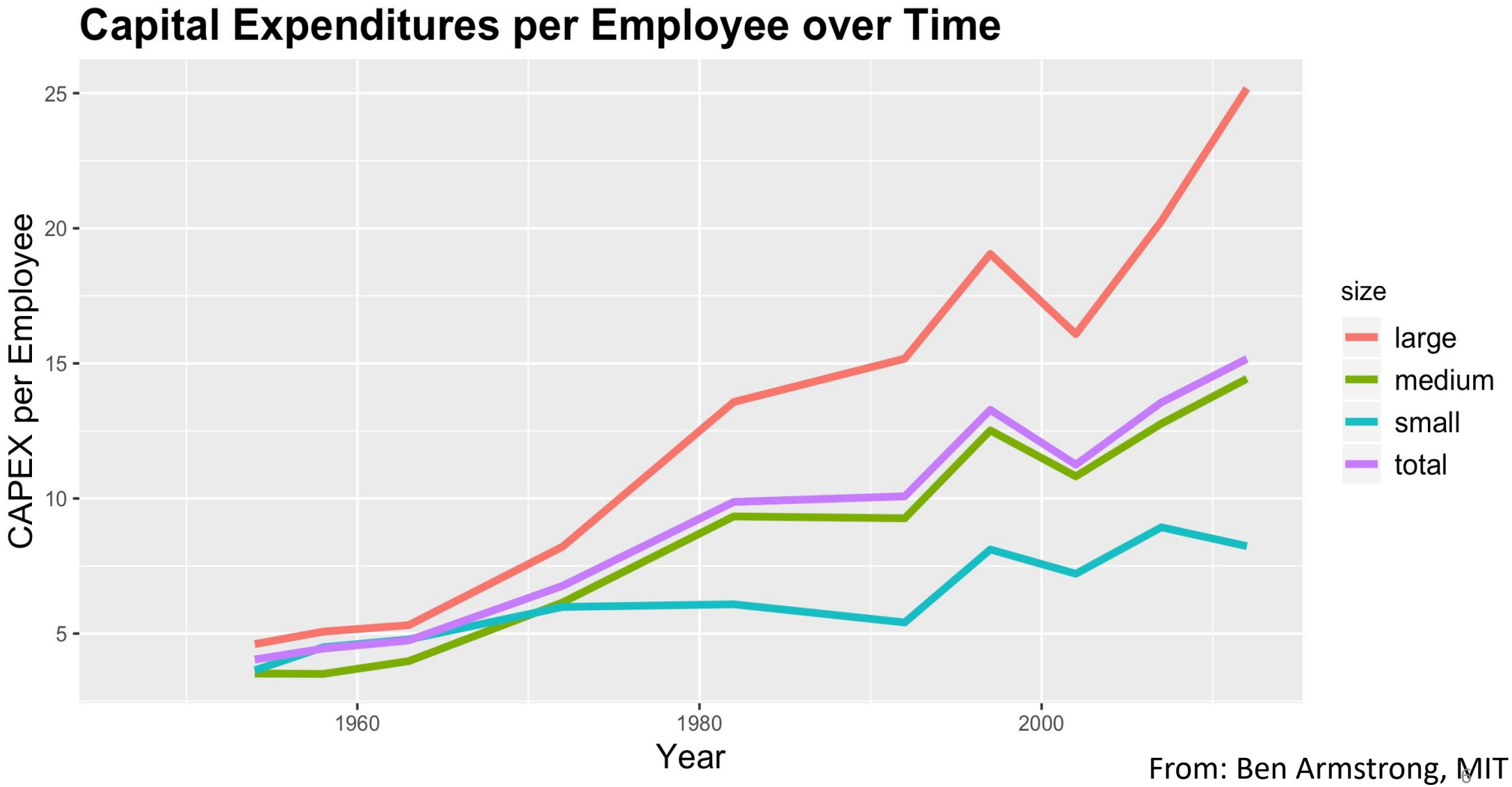
OECD Data - [From: Ben Armstrong, MIT 2/21]

Small and Mid-Sized Mfg. Firms Lag in Productivity:



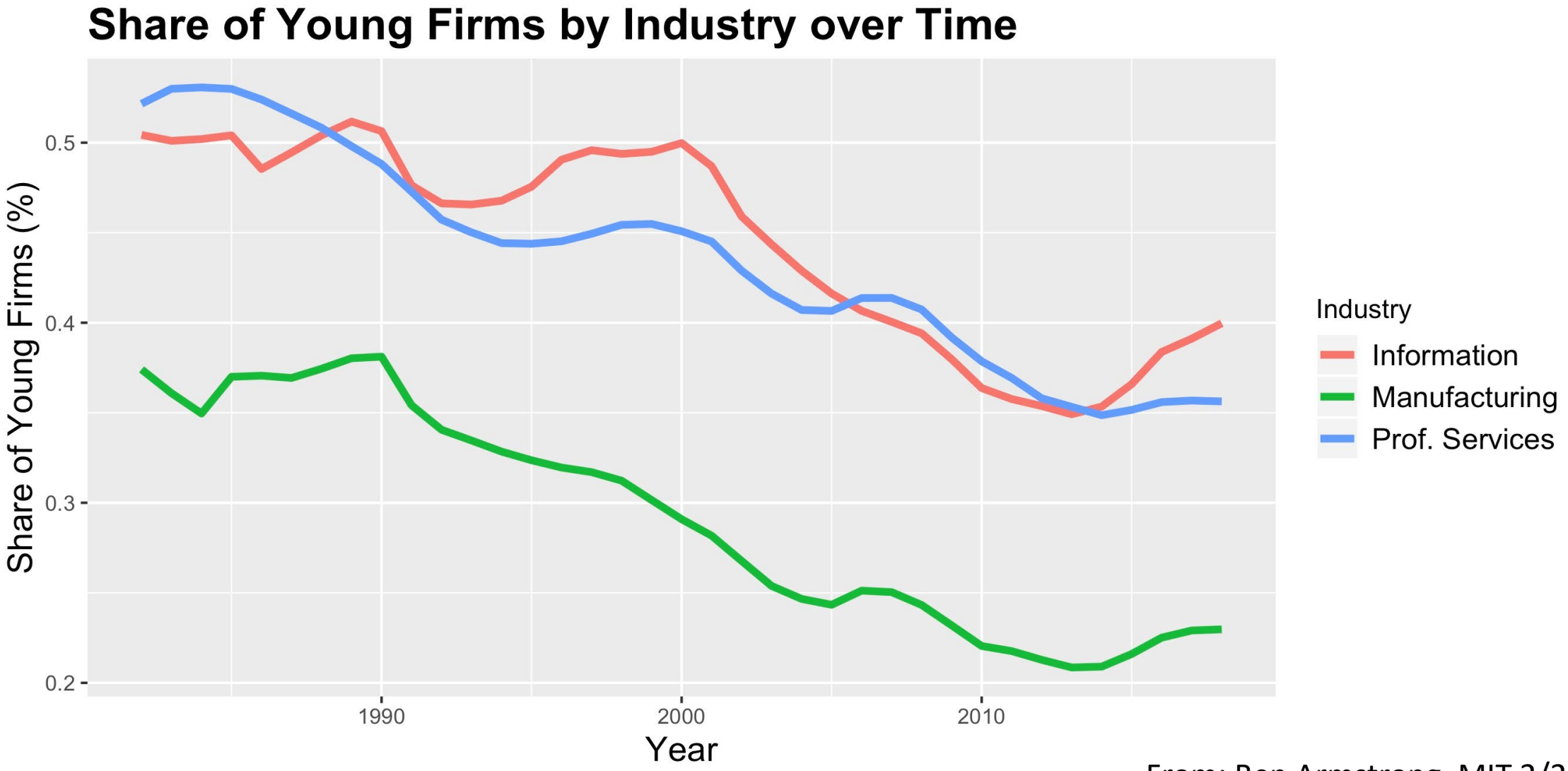
From: Ben Armstrong, MIT 2/21]

Productivity-related Capital Investments Stagnate at Small Mfg. Firms:



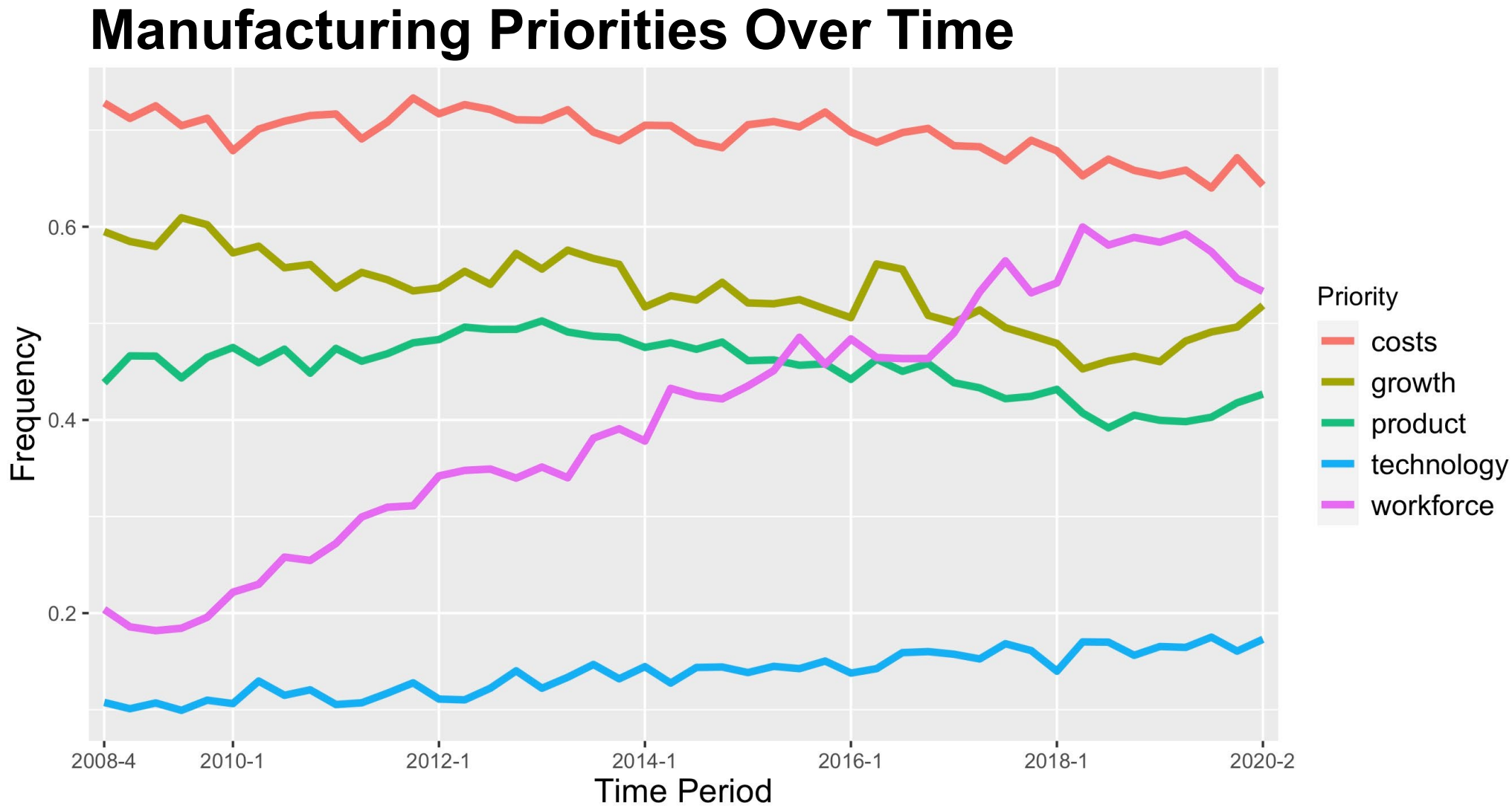
From: Ben Armstrong, MIT 2/21]

Nos. of New Entrepreneurial Firms in Decline in Manufacturing:



From: Ben Armstrong, MIT 2/21]

Workforce is a rapidly rising priority



MEP National Survey Data [from Ben Armstrong, MIT 2/21]

Key Underlying Manufacturing Issues:

- **Productivity** and mfg. **capital investment** at historically low levels
- **US lost 1/3 of its mfg. workforce** from 2000-2010
- **Output declined** significantly – dropped starting in 2000, only got back to 2000 levels in 2018
- **Mfg. not seen in the US as part of innovation** –R&D only, fragmented view
- The ”**innovate here/produce there**” problem = “produce there/Innovate there” – tie between innovation and manufacturing
- **Lesson from Germany**: 60% higher mfg. wages, massive surplus in mfg. goods including with Asia
- **Disconnected workforce education system** – and US firms historically favor capital investment over workforce investment for productivity
- **Social disruption** – decline in mfg. jobs related to decline in the US middle class

Gaps in the U.S. Production Innovation System = Capabilities Problem

- ***Signals of Gaps in Innovation System:***
  - ***productivity low,***
  - ***supporting ecosystem weak,***
  - ***scale up problem,***
  - ***delinked innovation and production,***
  - ***weak workforce training***
    - **= *Social Disruption***

    - ***Way out? Apply innovation system model?***
    - ***Core idea: Create new capabilities around system innovation – Advanced Manufacturing Institutes***

Advanced Manufacturing - Definition

- *German and Europe*: use the term “Industry 4.0” – it’s digital production, IoT, machine learning, etc. – entire focus is on digital
- *US*: uses term “Advanced Manufacturing” – captures many more developments than digital – includes digital, but also robotics, advanced materials, power electronics, photonics, lightweight metals, composites, flexible electronics, cyber security, biofabrication, etc.

Workforce Education Findings from National Academies October Report:

Background – Our Workforce Education Problems

- **Disconnect between work and learning**
- **Disinvestment by government and employers**
- **Disconnected federal programs**
  - **Labor Department** training programs don't **reach higher technical skills or incumbent workers**
  - **Education Department** programs are focused on **college degrees rather than workforce** needs and they are not **not linked** to the Labor Dept. programs.
- **Vocational education** in secondary schools was **largely dismantled**
- **Community colleges are underfunded**. They **lack resources to provide advanced training in new fields** and their **student completion rates are too low**
- **Lifelong learning is missing**.
- **Colleges and universities are disconnected from workforce education**
- **Broken a broken labor market information system**
- **Legacy sectors** – hard to change

Background on the scope of the report:

- In 2020, the OSD ManTech asked the Academies to perform a second rapid response study to examine three important suggestions from the first study. The Statement of Tasks for the Phase 2 Study is to provide general strategic guidance in:
  a) Task 1: Protocols for conducting long-term engagement assessments of the MIIs, including evaluation criteria;
  b) Task 2: Best practices in education and workforce development (EWD) for the MIIs, including scale-up methodologies for collaborative efforts by the MIIs in EWD; and
  c) Task 3: Steps for improving MII linkages with other parts of the DOD and with the broader federally funded research enterprise;

- An Interim Report focused on Task 1 was provided in April 2021

- The Final Report was produced in October 2021 from this phase two study documents findings and recommendations relevant to Tasks 1 to 3, with a focus on Tasks 2 and 3.

Background: the Oct. Report Committee

- WILLIAM B. BONVILLIAN, Massachusetts Institute of Technology, *Co-Chair*
- THOMAS M. DONNELLAN, Applied Research Laboratory, Pennsylvania State University, *Co-Chair*
- MEGAN BREWSTER is the VP for Advanced Technology at Impinj
- GAIL L. (DOLAN) HAHN, Boeing
- THERESA KOTANCHECK, Evolved Analytics, LLC
- MICK MAHER, Maher & Associates, LLC
- MICHAEL MCGRATH, Independent Consultant
- A. GALIP ULSOY, NAE, University of Michigan, Ann Arbor
- BEN WANG, Georgia Institute of Technology

Staff

- ERIK SVEDBERG, Senior Program Officer, National Materials and Manufacturing Board (NMMB), *Study Director*
- MICHELLE SCHWALBE, Acting Director, NMMB, Director, BMSA
- JAMES LANCASTER, Director, NMMB and the Board on Physics and Astronomy (retired)
- NEERAJ P. GORKHALY, Associate Program Officer
- JOSEPH PALMER, Senior Project Assistant
- AMISHA JINANDRA, Research Associate

Task 2, Chapter 3 – Education and Workforce Development – relevant tasks to *your* report

- Task 2(a) - Workforce Education Models from Across the Nation Relevant to MII Workforce Efforts
- Task 2(d) - Online Education as a Scaling Mechanism for Workforce Education
- Task 2(e) - Credentials and Certifications

Task 2(a) - Workforce Education Models from Across the Nation Relevant to Manufacturing Innovation Institute Workforce Efforts

- For Workforce Ed Tasks MIIs should be:
- Developing, with industry and education institution involvement, ***knowledge, skill, and ability (KSA) elements and corresponding competencies;***
- Forming ***regional engagements*** around workforce education needs;
- Developing ***education materials with and to be used in its education and industry ecosystem***;
- Working with industry to develop or apply ***industry-recognized credentials***;
- Developing ***online education materials*** available to industry and educational institutions.
- ***Mapping skill demand*** and developing ***skill roadmaps***, both regionally and nationally

Task 2(a) - Many of the optimal nationwide best practices listed below could inform the recommended MII workforce efforts:

- Approaches to Curriculum Design
  - Engage with groups of employers – more efficient and lasting than single employer
  - Statewide industry & Community College (CC) coordination mechanisms (Ohio)
  - Reach all 3: new entrant, underemployed and incumbent workers (Assnuntuck CC)
  - Short courses w/stackable credentials leading to degrees. certifications (Valencia CC)
  - Modular approaches to curriculum (Monroe CC, Rochester)
  - Tie degrees to industry-recognized credentials (Ivy Tech, Indiana)
  - Apprenticeships (break down the work/learn barrier – Trident Tech)

Task 2(a) – nationwide best practice approaches, con't

- Preferred approaches for Program Content
  - Systems thinking – the "why" not just the "how" – ability to manage systems across a factory floor, not just one machine
  - Hub and Spoke design – add adv'd mfg. skills to hub of systems thinking
  - Completion: build remedial programs into career programs (Tenn. TCATs)
- Preferred approaches for Scaling up Programs
  - Use online education for blended learning model
  - Access to Adv'd Mfg. Equipment – regional equipment-sharing (Conn. CC's)
- *Note: each best national practices tracks into MII recommended efforts*

Task 2(a) – Nationwide Preferred Approaches Recommendation:

- **Recommendation 3.1: OSD ManTech should encourage preferred approaches for workforce education delineated in this report and listed in the above findings be included by MIIs through the best practices set out in the Interim Report: forming regional engagements around workforce education needs; developing education materials with the MII's education and industry ecosystem; developing, with industry and education institution involvement, knowledge, skill, and ability (KSA) elements and corresponding competencies; working with industry to develop or apply industry-recognized credentials; developing online education materials available to industry and educational institutions, and mapping skill demand and in developing skill roadmaps. In furthering these best practices, NSF's ATE program, NIST's MEP program, DoD's OLDCC program, Labor Department workforce and apprenticeship programs, and other agency workforce programs, could be expanded or new collaborators on these efforts. OSD ManTech should also encourage the MIIs as a network to strengthen ties with programs with connections to community colleges that can help build and spread their programs in these areas. ManTech should provide leadership for MIIs in these collaborations and on the MII networking that will be required for creating training packages across technology areas to meet industry needs.**

Task 2(d) - Online Education as a Scaling Mechanism for Workforce Education

- Online is a critical way to scale workforce education
- New technologies – simulations, gaming, VR/AR can enhance online for workforce ed – enable hands-on approaches need for workforce ed
- Online education can apply new learning science (ex's: ten minute chunks, desirable difficulties, frequent quizzes, interleaved content, assessment and feedback loops) to optimize effectiveness
  - asynchronous video not zoom, which misses the learning science
- Blended is best

Task 2(d) Recommendation

- **Recommendation 3.5: Given manufacturing workforce needs and because of their importance as a scaling mechanism, OSD ManTech should continue to encourage, support, and expand the initiatives for online and blended workforce education by manufacturing institutes. Online education and related blended learning should become a significant focus of institute education and workforce development efforts, including their efforts with their regional manufacturing ecosystems, because of its potential to scale up skills training in their advanced manufacturing fields. This should include support by OSD ManTech for: institute use of new educational technologies such as computer gaming, simulations, blockchain certifications, virtual and augmented reality (VR/AR), and digital tutors; incorporation by institutes of online materials of pedagogies that reflect learning science advances; collaborations between ManTech and military services' VR/AR training simulation development programs; expanded use by institutes and other DoD agencies of the Open edX platform for access to online education materials; and other approaches noted in this discussion.**

Task 2(e) - Credentials and Certifications

- Industry credentials:
  - tell employers what skills employees have,
  - tell employees what skills they need, and
  - tell education institutions what to educate for
- Yet: inconsistently or not widely used in manufacturing
- Industry-recognized credentials can be a foundation for a strong workforce in advanced manufacturing
  - Ex.: Cisco/Microsoft skills certifications key to IT sector talent
- MIIs with their ties to industry are in good position to help develop these credentials

Task 2(e) – Credentials, con't

- 2 kinds of MIIs:
  - "closer-in" – technologies starting to enter factories
  - "further-out" – technologies still in development
- Further-out MIIs can work with industry members in establishing new credentials in their technology areas
- Closer-in MIIs can review and endorse established credentials
  - Ex: ARM has reviewed credential packages and developed KSA and is certifying adv'd robotics programs in CCs as endorsed by ARM

Closing Thought – The "Technologist"

- Systems thinking – the "why" not just the "how"
- Ability to manage systems across a factory floor, not just one machine – *technologist not just technician*
- Create new category *between engineer and technician*
  - *Engineer – "upstairs" - design*
  - *Technologist – less design, more process, can do interoperability across equipment and systems on the factory floor*
- *Hub and Spoke curriculum model –*
  - *Hub – mfg. systems, processes, budgeting, personnel*
  - *Spokes – particular advanced manufacturing skills – 3D printing, robotics, digital production, data analytics*