



Open Learning

Advanced Manufacturing and the University Role in Workforce Education

*Conference: “Connecting
Credentials and Degrees in
Manufacturing”*

*Sponsors: APLU, UPCEA,
WorkCred*

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3 TOPICS:

- I. *The US Manufacturing Problem – 6 Findings*
- II. *Response: Advanced Manufacturing Innovation Model*
- III. *Focus on Workforce Education*

Part I – What is the Manufacturing Problem?

Finding One: Signal from Manufacturing Job Loss

- US lost 5.8 million manufacturing jobs from 2000 to 2010 – one third of production jobs
 - US thought manufacturing **output** was holding firm, but it wasn't - on reexamination, finding it was in decline (in 16 of 19 sectors)
 - So ***didn't get the productivity gains it thought***
 - ***US productivity: 1995-2005: 2.5%; 2005-2015: 1% range***
 - **Capital, plant, equipment, IT investment down in 2000s**
 - **Major trade deficit: \$800b manufactured goods**
- Job loss data: signal that US manufacturing was ***hollowing out and facing international competition – Decline in productivity levels: signal of innovation gap***

Finding Two: “Home Alone”

- Reports tell us for the past three decades U.S. has been thinning out the manufacturing ecosystem
 - US used to have firms and supply chains that were very vertically integrated
 - US hit on a financial model of emphasizing quarterly returns, which led us to reduce risk by making our firms focus on “core competency” and go “asset light”
 - *And complex technologies require more specialized firms*
 - So the shared assets of training, bringing best practices to suppliers, thinned out
 - 60,000 factories closed in the 2000s
 - **The small & midsize companies in the US system are now much more**
“home alone” = innovation system gap

Finding Three: Scale Up --> System Gap

- **US has 3 manufacturing sectors:**

- **1) Big multinationals** – they are global, they can get production efficiencies by producing in lower cost countries and they must be in all the global markets
- They're OK, although they are increasingly producing abroad

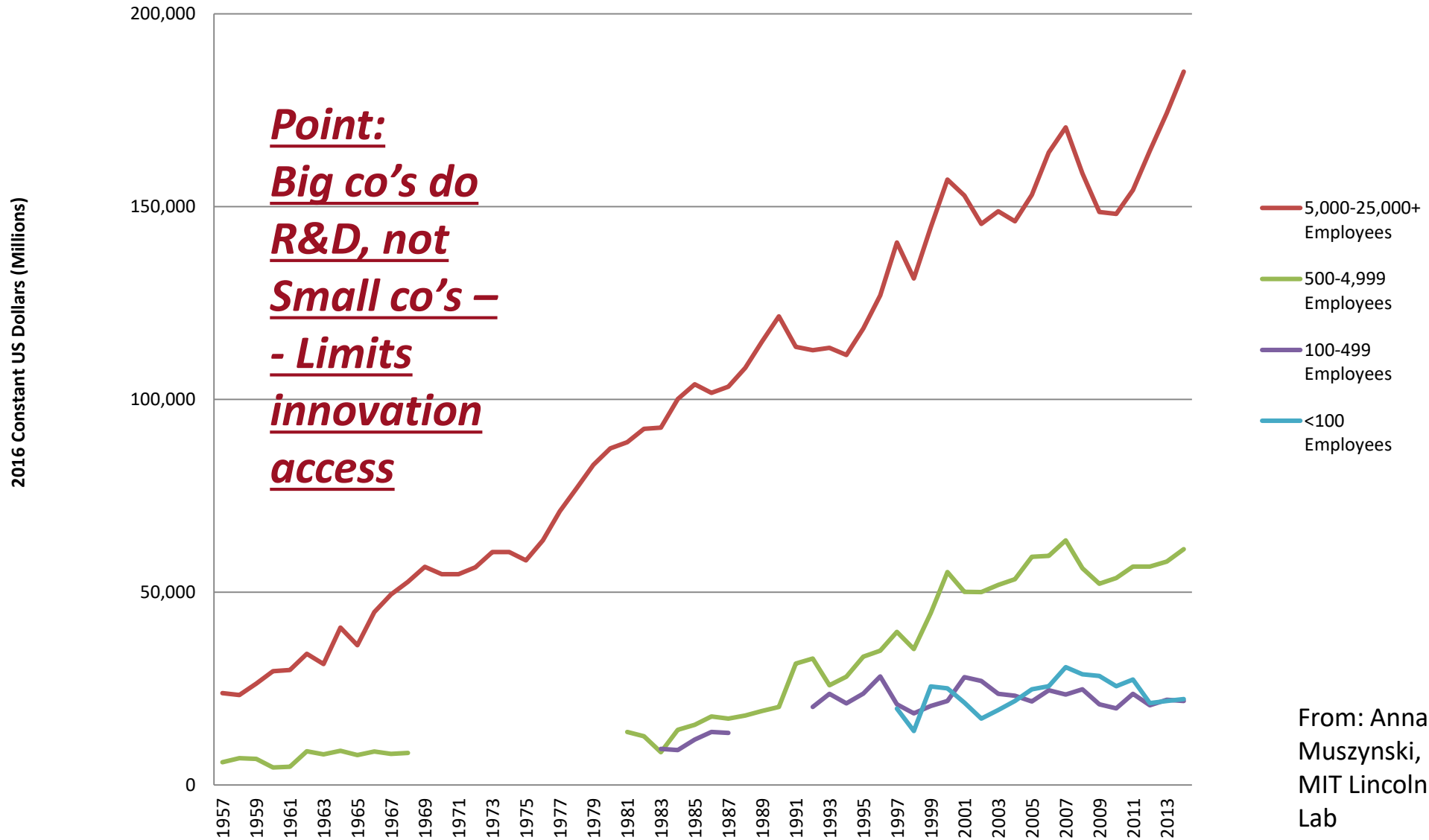
- + Two More Vulnerable Sectors – these face a scale-up gap:**

- **2) Main Street firms** – they do 46% of U.S. manufacturing, there are 250,000 small and mid-size firms (under 500 ee's)
- They **have trouble getting production scale up funding**, they're *thinly capitalized*, must be risk adverse to survive, and don't do R&D so limited access to innovation (but can be innovative about process)

- **3) Entrepreneurial startups that make something** –

- they do well until they have to **scale up for production** of their product – they **lack financing for scale-up** here – Venture Capital doesn't fund this – So they turn to contract manufacturers abroad

Private Industrial R&D Funding in the U.S. by Company Size (1957 - 2014)

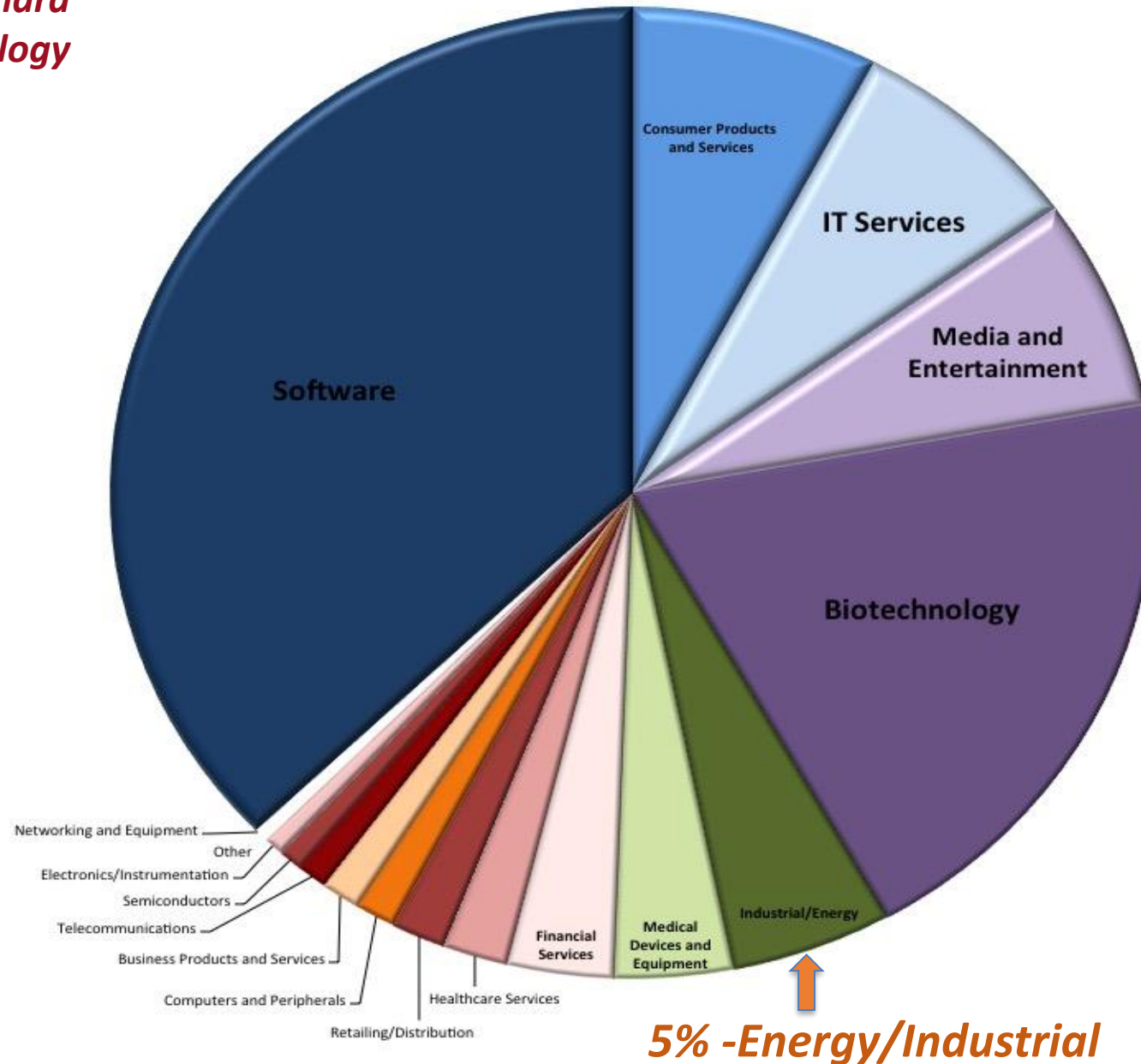


From: Anna Muszynski, MIT Lincoln Lab

Sources: "Domestic R&D Funded by Companies Doing Business in the US" 2014 - The NSF Business R&D and Innovation Survey (BRDIS), *in press*; 2008 to 2013 - The NSF Business R&D and Innovation Survey (BRDIS), <https://www.nsf.gov/statistics/srvyindustry/>; 1980 to 2007 - The NSF Survey of Industry R&D (SIRD), <https://www.nsf.gov/statistics/iris/>

*Point: Venture
Capital withdraws
from "hard"
technology*

Total VC Investment in 2015



Source: P. Singer,
MIT, 7/16 from
NVCA & PWC data

Finding Four: Production must be seen as part of the Innovation System

- Manufacturing not pictured in the US as part of the innovation process
 - US focus is on only R&D: fragmented view
 - Innovation is a system, from early-stage research through manufacturing
- Treat production as critical element that must be connected to innovation system
 - or risk innovation erosion

The Tie between Innovation and Production

- US had: *innovate here/produce here* – got full spectrum of gains
- Then US did: *innovate here/produce there*
- But - for most products need to tie innovation closely to initial production
 - Need dense feedback loops as you do product design- initial production requires very creative engineering and design – it's part of innovation
 - So if you shift production capability, in many cases innovation capability has to follow it
 - Result: *Produce there = Innovate there*
- Innovation is U.S. strong suit –what it does best
- But if many important innovations have follow production, endangers US innovation strength – *creates system gap* to core
- And Innovation is the key growth factor

Finding Five: Lessons from Germany – Illustrate U.S. System Gaps

- US thought that it had to lose manufacturing jobs to low cost producers in Asia because it was high wage.
- But Germany is high wage and high cost – German wages and benefits are 60% higher than the U.S.
- Germany runs a major manufacturing surplus, including a manufacturing surplus with Asian nations
- Germany has a deep ecosystem for their manufacturers, small and large – they aren't "home alone" – shows U.S. gap
- Extensive collaborative R&D shared by industry- gov't-universities around manufacturing technologies and processes – Fraunhofer Institutes
- Shared training system for their workforce – shows U.S. gap
- Ways to link their supply chains for rapid scale up
- Some German practices don't apply, some do

Finding Six: Manufacturing Decline = Social Disruption

- Between 2000 and 2010, U.S. manufacturing employment fell by one third
 - Only recovered 20% by 2018
- Manufacturing - important middle class pathway for high school educated males –
- Importantly, median income of men without High Sch. diploma fell by 20% between 1990 and 2013; - men w/High Sch. diploma or some college fell 13%
- U.S. now has historically high labor non-participation rate for prime age workers
- Clear a signal of:
 - A loss to middle income ranks and growing inequality
- *Can Advanced Manufacturing speak to this?*

The Hourglass and the Barbell:



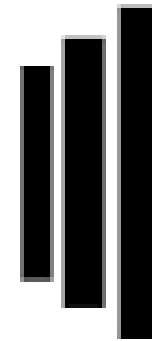
<---- Resources, Suppliers,
Components, R&D

<--- Production (12m jobs)

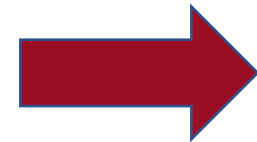
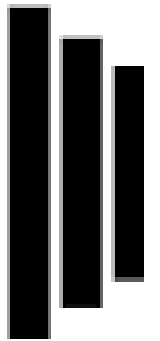
<--- Distribution, Sales, Life
Cycle

***AND: Value Chains run
throughout***

Upper
Middle
Class



Lower end
Lower pay
Services
Sectors



Middle Class
- Sliding
into
Services
Sectors

Problem Summary:

- Manufacturing job loss was not productivity driven
- Ecosystem for U.S. Manufacturing Firms has thinned out
- Big Scale-Up problem for small, mid-sized, and start-up firms
– financing gap for scale-up
- U.S. Delinked innovation/production
- But: Manufacturing is part of Innovation System
- Germany: strong mfg. ecosystem tied to innovation
- Lost 1/3 Mfg. Jobs – manufacturing is the largest job multiplier, far higher than services - signal of decline
- Result: social disruption

Gaps in the U.S. Production Innovation System

- **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?***

Part II – the Remedy

- Apply the Innovation System to the Problem
- Fill System Gaps, build new capabilities at the national and regional levels
- i.e., “Advanced Manufacturing”

Policy Background: *Is Advanced Manufacturing - - A New Innovation Model?*

- *The Four Innovation Models:*

1. “Pipeline Model”

- US focus since postwar: “Front end” of Innovation System
- Fundamental research is role of US R&D agencies
- Performs potential breakthrough research, can lead to radical technology advance
- “Technology Push”/Technology Supply

2. “Induced Innovation”

- Industry led – does incremental advance
- Responds to “Technology Demand” in Market – “Demand Pull”

3. “Extended Pipeline”


- Role of Department of Defense
- Connected model – all stages of innovation

Issue: The innovation Pipeline:



THE INNOVATION PIPELINE:

Research-> Dev-> Prototype-> Demo-> Testbed-> Production-> Market

NSF, DOE OS, NIH, etc.: 

Pipeline Model – Basic Research

DOD:



“Extended Pipeline” Model - DOD has a “Connected System”

INDUCED INNOVATION – INDUSTRY:



Development and Post-Development focused

The 4th Innovation Model:

- “Manufacturing-Led” Innovation
 - Innovation system focus is on innovation in production technologies and processes
 - Examples:
 - US created mass production in late 19th century
 - Japan created “Quality Manufacturing” in 1970s-80s
 - Manufacturing-Led innovation systems:
 - Germany, Japan, Korea, and now China
- *BUT: END OF WW2: Because the US led in mass production, it just assumed production leadership*
 - *Focused its innovation system on research*
 - *not production*
 - **Time for the US to do both?**

Idea: Scientists/Engineers Say There Are: New Manufacturing Paradigms

Are there new advanced manufacturing “Paradigms” –

• **Idea:** raise efficiency, compete with lower cost economies; could lead to restoration of mfg. leadership? – And innovation is its own reward, creates new opportunities -- some examples:

- **“Network centric”/Digital Production**
- **Advanced materials**
- **Nanomanufacturing**
- **Mass Customization**
- **Distribution efficiency**
- **Specific Technologies: Photonics, Advanced Composites, Biofabrication, Power Electronics, etc.**

The 2012 & 2014 Advanced Mfg. Partnership Reports – 4 Basic Recommendations:

- *Apply still strong innovation system to manufacturing*
- *Develop Transformative Technologies – w/Technology Strategies Linked to R&D*
- Implement **Manufacturing Institutes** and network them
- Form a Technology Scale-Up/Policy
- **And: Demand-Driven Workforce Solutions**

Collaborative, Public/Private Partnership - Innovation Model

New Model - Advanced Manufacturing Institutes

- Advanced Manufacturing Partnership (AMP) - idea:
- “Advanced Manufacturing Institutes” - 14 now
 - Collaborative–industry/univ/gov’t R&D – in a way, Sematech model – bring the innovation system into production system
 - Testbed role / Workforce education role
 - Bring on new technology paradigms – develop roadmaps
 - Cost shared between: federal gov’t/industry/state gov’t
 - VERY COMPLEX MODEL – 100+ENTITIES IN EACH INSTITUTE
 - DOD OFFICIAL: “Like standing up a country”
 - VERY ambitious

Part III – Workforce Education

- Why is Workforce Education so important for Advanced Manufacturing?
- How should we think about it?

We Have No Advanced Manufacturing Curriculum

- New skills will be needed for advanced manufacturing -
 - Advanced materials and composites, power electronics, biofabrication, robotics, digital production technologies, data analytics, cybersecurity, functional fibers, photonics, etc. – ***all require new skills***
- We don't have the **curriculum** for these new skills
- We don't have the **delivery systems** for these new skills
- Manufacturing is at the leading edge of technology – it is the first adopter of productivity-enhancing technology because it scales
 - It is in advance of what will be a larger new skills societal problem
- ***We won't do advanced manufacturing unless the workforce is ready to implement it***

Critical New Role: Workforce Training

- Germany: Fraunhofer Institutes have a “Fraunhofer Academy”
- It trains apprentices for “mittelstat” small and mid-sized as well as large firms in the advanced technologies that its Institutes are creating
 - learning by doing, classroom and workplace
- The Training is the ADVANCED MFG. TECHNOLOGY DISSEMINATION MODEL
 - The way advanced manufacturing technologies get into company plants –
 - Learning walks on two feet, not through plans

Meanwhile the Workforce is Upskilling

- Jobs increasingly tend to go to **college educated**
- **11.6m jobs created between 2010-2018**
 - **11.5m** went to those with college or some college education
 - **80,000** went those with HS education or less
- College: **default credential?** – not well-tied to workforce skills
- But **growing IT**, demanding new skills
- **Result:** New high or middle skills jobs will require education beyond high school
- **Barrier:** 1/3 of Americans over 25 have a 4-year college degree

Workforce Education System Problems

- Decentralized labor markets
- Weak labor market information system:
 - Workers don't know what skills they need
 - Educators don't know what skills to educate for
 - Employers don't know what skills workers have
- Transition from school to work a problem in the US
 - Contrast: Germany, Austria, Switzerland
 - H.S. diplomas not enough and vocational H.S. largely ended
- Colleges are not engaged in workforce preparation
- No transferable skills certification system in most fields
- Ed and Labor Dept programs are not aligned
 - Labor Dept. : Programs focused on unemployed and underemployed, not upskilling for incumbent workers
 - Education Dept. : Pell grant programs are only for degree programs not workforce

New Tool – New Education Technologies: Online Plus

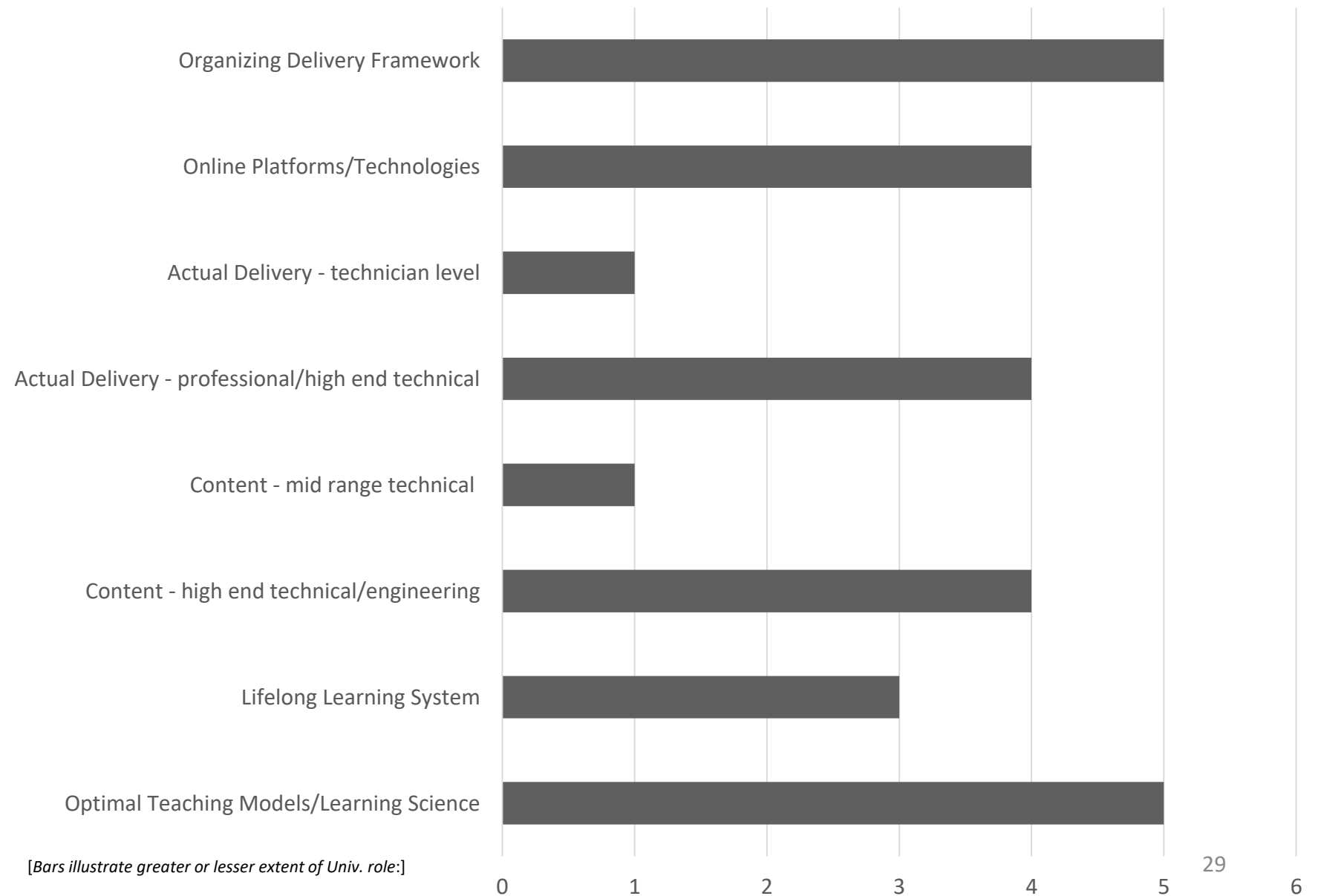
- Becoming widespread and can be optimized with blended learning – **CAN SCALE**
- Can join online with:
 - **VR/AR** technologies: Learning by doing
 - **Computer gaming and simulation**
 - **Blockchain certification**: User owns credentials
 - **Bootcamps**
 - **Digital Tutors**: Need AI advancement to combine shared education platforms (MOOCs) and individualize instruction and assessment

Question: What can a University do?

What is the University Role?

Roles in Different Areas:

("notional" chart)



Emerging Policy Menu:

- **New education technologies** - need development and implementation – VR/AR, gaming, digital tutors/AI – DOD role
- **Short Courses** – BUT must connect to CC certificates, degrees (NSF ATE dev. models, DOL workforce bds.)
- **“Trifecta”** - CC programs for CC students, incumbents, HS students (NSF ATE, Dept. of Ed, states)
- **Apprenticeships or “Apprenticeship Light”**- youth and CC – in fields that have clear lines for increased responsibility and wages, ‘er-’ee agreements (DOL)
 - Need for actors to coordinate: CC’s, employers, regional associations, state gov’t
- **CC completion rate**
- **Technical and Comprehensive HS’s** – state role
- **Expanded employer role** – apprenticeships, training, standards
- **New curriculum for advanced fields** – start with adv’d mfg. – Adv’d Mfg. Institutes/DOD Mantech/DOE/states
- **Unifying efforts at the state level** – states – across Labor/Ed
- **Labor market Information system** – DOL

Examples of New Workforce Models for Universities

- **State plan for developing advanced manufacturing education** across Voc Ed HS's, CC's, state univ's, in *Mass.* – Workforce Bd.'s – 5 mfg. institutes involved including AIM Photonics – integrate disconnected fed. programs at state level
- **Education Roadmaps** for Advanced Manufacturing technologies - *AIM*
- **Workforce Education Development Center** – *Clemson* – adv'd mfg. online courses developed for state's 17 technical colleges
- **Integrating new Engineering Manufacturing Masters with Greenville Tech** mfg. apprentice program – *Clemson* – reconnecting engineering and the factory floor
- **Apprenticeship program at technical univ. level** – *Germany* – job/learn, coop
- **Other Opportunities:**
 - **Computer science** education online and blended
 - **Lifelong Learning** programs
 - Topic today: **certificates** in adv'd mfg. skills related to degrees

Big Job ...

Big Opportunity!