Deconstructing Human Capital to Construct Nestedness

HYEJIN YOUN

Northwestern University
Kellogg School of Management

Northwestern | Kellogg

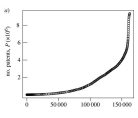
Modern economies **immensely diverse complex** goods and services

Excerpt from Korean Show, My love from the star

How can we generate such diverse complex goods and services?

The increasing complexity puts us under the pressure of acquiring an ever-increasing specialized and yet diverse skill portfolio in order to stay effective members of complex economy. Specialized workers' efforts and know-how of people in vast networks spanning across the glob are coordinated.

- People and firms specialize in different activities
- Economic efficiency increases, more productive
- Observations:
  - The number of individual activities increases
  - The number of interactions increases
  - Increasing coordination costs.



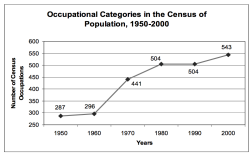
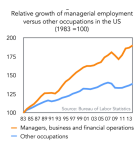


Chart 1. Counts of the Census occupational categories in years 1950-2000.



Complexity and high productivity
immense pressure on specializations

Two different specializations

Division of labor (Deskilling)
–Increases productivity.
–Task-specific.
–Often learning-by-doing?
–Loosing bargaining power
–Less valuable

Flywheel assembly line at the Ford Motor Company's MI in 1913 *[Politico]*.

Division of knowledge
(Unique Skills)
– Professions
– Increasing bargaining power
– More valuable

Software engineer

Hardware engineer

Increasing complexity

First stone tool

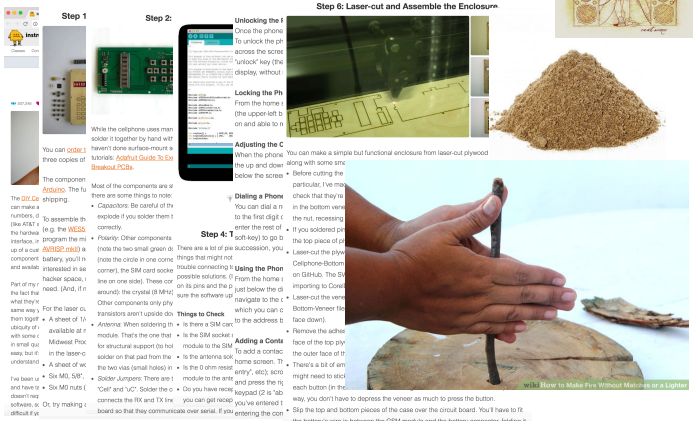
The teardrop-shaped hand-axes date to about 1.76 million years ago, and would have been used for a range of tasks from chopping wood to cutting up meat.

First iPhone

I can make it alone *Can I make it alone?*

But it would be more productive dividing our labor

Make a cellphone from scratch



What about a toaster?

What about a toaster? Thomas Thwaites

Hand Mining Mica

Suitcase Full of Iron Ore

Microwave Metal Melting

I, Pencil

I have a profound lesson to teach.

Just as you cannot trace your family tree back very far, so is it impossible for me to name and explain all my antecedents. But I would like to suggest enough of them to impress upon you the richness and complexity of my background…

My family tree begins with what in fact is a tree, a cedar of straight grain that grows in Northern California and Oregon. Now contemplate all the saws and trucks and rope and the countless other gear used in harvesting and carting the cedar logs to the railroad siding. The logs are shipped to a mill in San Leandro, California. Can you imagine the individuals who make flat cars and rails and railroad engines and who construct and install the communication systems incidental thereto? …

My "lead" itself..is complex. The graphite is mined in Ceylon. …shipped and those who make the string that ties the sacks and those who put them aboard ships and those who make the ships…is mixed with clay from Mississippi…treated with a hot mixture which includes candelilla wax from Mexico,

Simple? Yet not a single person on the face of this earth knows how to make me.

I, Pencil *by Leonard E. Read (1958)*
Freakonomics Radio, How Can This Possibly Be True? Stephen Dubner, 2016

Increasing complexity

First stone tool

The teardrop-shaped hand-axes date to about 1.76 million years ago, and would have been used for a range of tasks from chopping wood to cutting up meat.

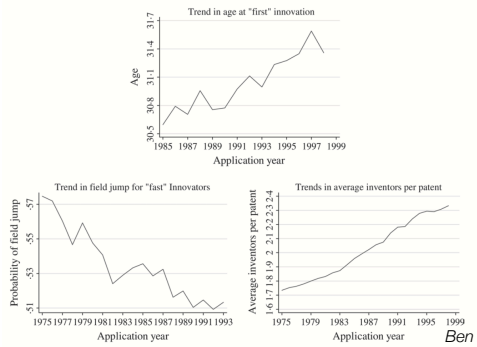
First iPhone

I can make it alone
But it would be more productive dividing our labor

I can't make it alone
division of knowledge

Market driven vs. complexity driven

- Our brain is FINITE: limited Person byte
- Capped by mortality and life cycle



Ben Jones, 2009

There is only so much we can learn

Two different specializations

Division of labor (Deskilling)
–Increases productivity.
–Task-specific.
–Often learning-by-doing?
–Loosing bargaining power
–Less valuable

Division of knowledge (Upskilling)
– Increases productivity
– Professions
– Long trajectory of learning
– Increasing bargaining power
– More valuable

How do we specialize our knowledge to become more valuable?

Physics → Calculus → Arithmetic

Pre-requisite dependency: sequence

There are steps… to get there

8.20 I January IAP 2021 I Undergraduate

Introduction To Special Relativity

Syllabus
Video Lectures
Readings
Assignments
Exams

Syllabus

Course Meeting Times
Lectures: 19 sessions / 4 weeks, 1.5 hours / session

Prerequisites
18.01 Single Variable Calculus

18.01SC I Fall 2010 I Undergraduate

Single Variable Calculus

Syllabus
1. Differentiation
2. Applications of Differentiation
3. The Definite Integral and its Applications
4. Techniques of Integration

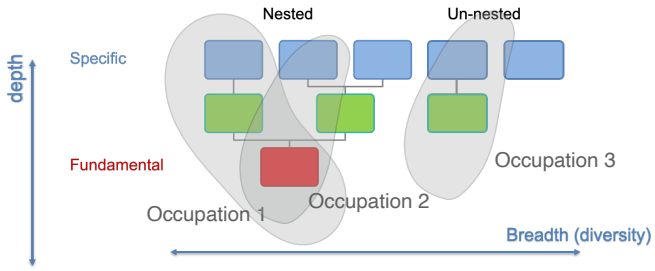
Syllabus

« [Previous](/courses/18-01sc-single-variable-calculus-fall-2010/pages/index.htm) I Next »

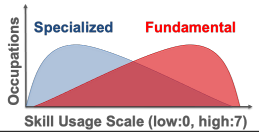
Introduction
Prerequisites
Single Variable Calculus is a first-year, first-semester course at MIT. The prerequisites are high school algebra and trigonometry. Prior experience with calculus is helpful but not essential.

Course Overview
Calculus is a foundational course at MIT; it plays an important role in the understanding of science, engineering, economics, and computer science, among other disciplines. This introductory calculus course covers differentiation and integration of functions of one

Skills are nested in hierarchy



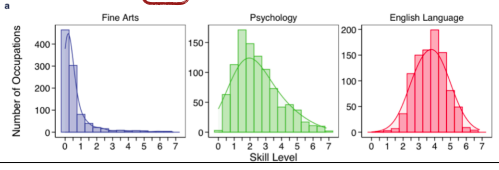
Distribution



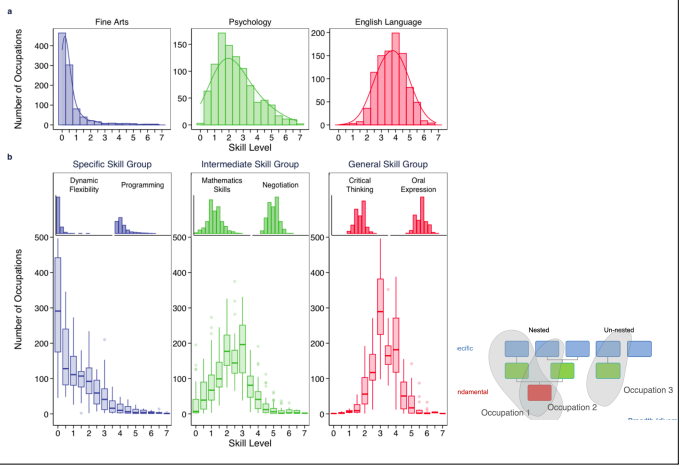
Data: O*NET

- Representative survey data of US labor
- About 1000 occupations, 120 skill items

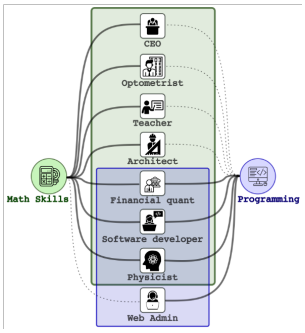
ONETSOC Code	Element ID	Importance	Level	Element Name	Occupation Title
29-1011.00	1.A.2.c.1	2	1.500	Reaction Time	Chiropractors
11-1011.00	2.B.5.b	4.120	5.500	Management of Financial Resources	Chief Executives
35-9021.00	2.B.3.m	2.500	2	Quality Control Analysis	Dishwashers
11-1011.00	2.C.1.f	4.100	5.020	Personnel and Human Resources	Chief Executives
29-1011.00	2.A.1.b	4	4.120	Active Listening	Chiropractors
53-2011.00	1.A.1.b.6	4	4	Information Ordering	Airline Pilots, Copilots, and Flight Engineers
53-2011.00	1.A.2.c.1	4.120	4.620	Reaction Time	Airline Pilots, Copilots, and Flight Engineers
53-2011.00	1.A.1.b.2	2.880	3.120	Originality	Airline Pilots, Copilots, and Flight Engineers
29-1011.00	2.B.3.b	1.750	0.750	Technology Design	Chiropractors
35-9021.00	1.A.4.a.3	2.380	2.120	Visual Color Discrimination	Dishwashers

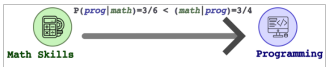


Skill Distribution across occupations

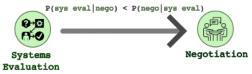


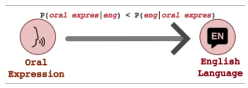
Extracting hierarchy and nestedness from **asymmetric** occurrences





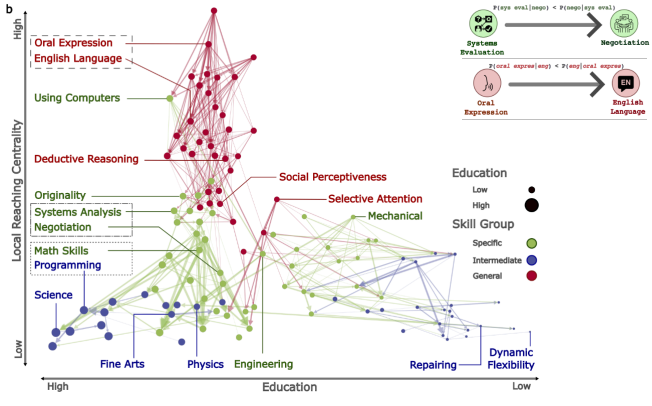
$$P(prog|math) = \frac{3}{6} < (math|prog) = \frac{3}{4}$$





Hierarchy and nested skills

Identifying dependency ties breaks **symmetric** relationship.



Application and Results:

- Nestedness classification
- Wage premium is entirely explained by general skills (not specific skills), which is surprising for specialization

Cross-sectional (snapshot) to Temporal (dynamics)

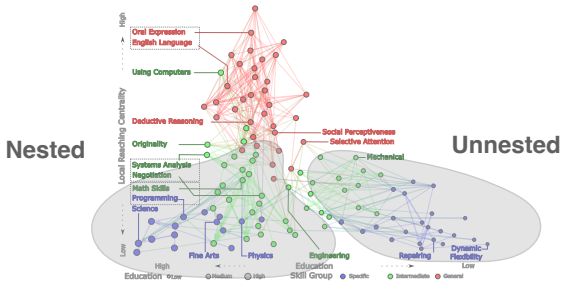
–Occupational age cohorts (CPS)
–Career trajectory (20M resumes in BurningGlass Technology)

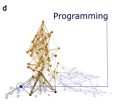
Implications:

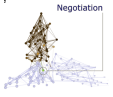
- classification change,
- demographic disparity,
- geographic distribution

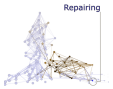
Applications: Human-Tech Ecosystems

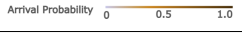
Nested vs. Unnested







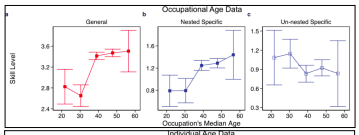




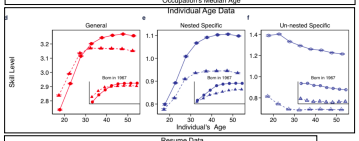
Skill Subtype	Skill Titles
Nested Specific	Science, Technology Design, Programming, Management of Financial Resources, Physics, Chemistry, Biology, Sociology and Anthropology, Geography, Medicine and Dentistry, Therapy and Counseling, Foreign Language, Fine Arts, History and Archeology, Philosophy and Theology
Un-nested Specific	Spatial Orientation, Multilimb Coordination, Response Orientation, Rate Control, Reaction Time, Wrist-Finger Speed, Speed of Limb Movement, Static Strength, Explosive Strength, Dynamic Strength, Stamina, Extent Flexibility, Dynamic Flexibility, Gross Body Coordination, Gross Body Equilibrium, Night Vision, Peripheral Vision, Glare Sensitivity, Sound Localization, Equipment Selection, Installation, Equipment Maintenance, Troubleshooting, Repairing, Food Production, Building and Construction
Nested Intermediate	Originality, Mathematical Reasoning, Number Facility, Memorization, Speed of Closure, Mathematics Skills, Learning Strategies, Persuasion, Negotiation, Instructing, Operations Analysis, Systems Analysis, Systems Evaluation, Management of Material Resources, Management of Personnel Resources, Clerical, Economics and Accounting, Sales and Marketing, Personnel and Human Resources, Computers and Electronics, Design, Psychology, Education and Training, Law and Government, Telecommunications, Communications and Media
Un-nested Intermediate	Visualization, Time Sharing, Arm-Hand Steadiness, Manual Dexterity, Finger Dexterity, Control Precision, Trunk Strength, Visual Color Discrimination, Depth Perception, Hearing Sensitivity, Auditory Attention, Operation Monitoring, Operation and Control, Quality Control Analysis, Transportation, Production and Processing, Engineering and Technology, Mechanical, Public Safety and Security
General	Oral Comprehension, Written Comprehension, Oral Expression, Written Expression, Fluency of Ideas, Problem Sensitivity, Deductive Reasoning, Inductive Reasoning, Information Ordering, Category Flexibility, Flexibility of Closure, Perceptual Speed, Selective Attention, Near Vision, Far Vision, Speech Recognition, Speech Clarity, Reading Comprehension, Active Listening, Writing, Speaking, Critical Thinking, Active Learning, Monitoring, Social Perceptiveness, Coordination, Service Orientation, Complex Problem Solving, Judgment and Decision Making, Time Management, Administration and Management, Customer and Personal Service, Mathematics Knowledge, English Language

Cross-sectional to temporal

- Skill structure comes from cross-sectional distribution of skills (snapshot)
- Let's look at temporal sequences with three datasets (1) Occupational avg. wage; (2) Occupational age cohorts; (3) Career trajectory (resume)



Data Source is Bureau of Labor Statistics, survey. The data covers all industry and comprehensive, but does not include sequences.



Gender ▲ Female ● Male

Data Source is CPS, a monthly survey sponsored by the Bureau of Labor Statistics and conducted by the U.S. Census Bureau. The data may not cover the entire industry, but includes fragmented sequences (2years) and demographic/geographic info.

Data Source is BurningGlass Technology, one of the world's largest real-time, proprietary databases of job openings and career histories. The data include resume where Δ can be directly measured, but no demographic data, and the biased industry distribution

Burning Glass Data

One of the world's largest real-time, proprietary databases of job openings and career histories. The data include resume where Δ can be directly measured, but no demographic data, and the biased industry distribution

7 M resumes and 15 M career moves
(No within-occupation moves and at least 12 months tenure)

Hyejin's Resume

- Physicist year 1
- Economist year 2
- Social Scientist year 3
- …

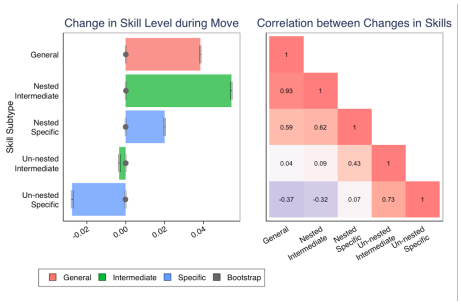
ONET Skill Data

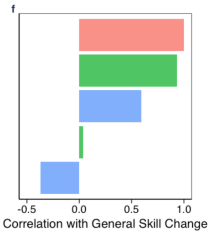
Job \Skill	Physics	Economics	Speaking
Physicist	6.46	1.17	4.75
	Δ= 5.29	Δ= + 4.06	Δ= -0.5
Economist	1.17	5.23	4.25
	Δ= -0.61	Δ= - 0.37	Δ= +0.63
Social Scientist	0.56	4.86	4.88

Nested General

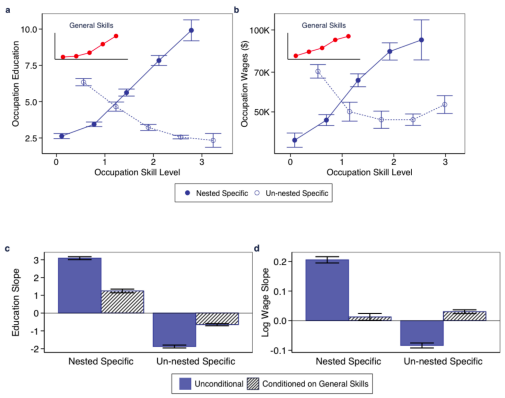
$$\Delta_s = [\Delta_{General}, \Delta_{Nested\ Int.}, \Delta_{Unnested\ Int.}, \Delta_{Nested\ Specific}, \Delta_{Unnested\ Specific}]$$

Burning Glass Data

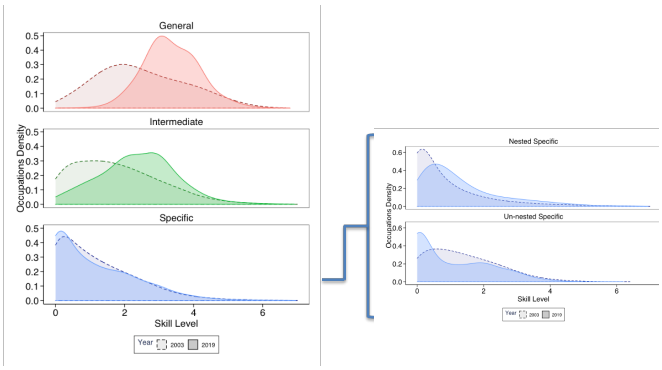




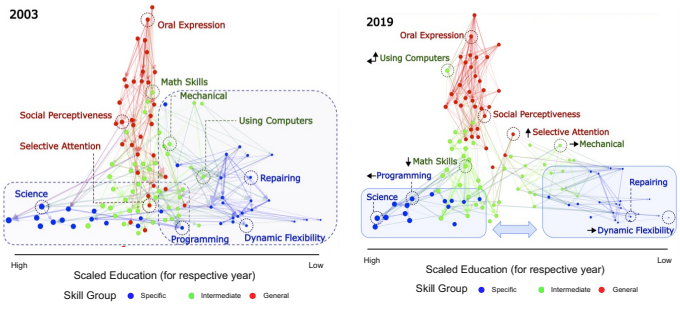
Investment and Payoffs General Skills



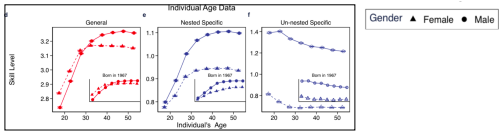
Recent Skill Changes

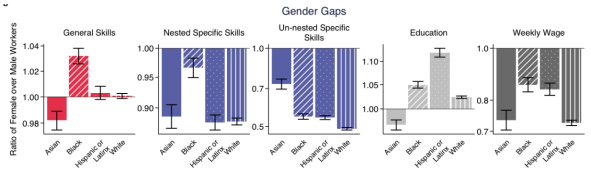


Wider gap between nested and unnested

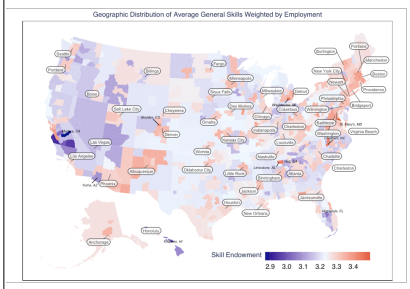


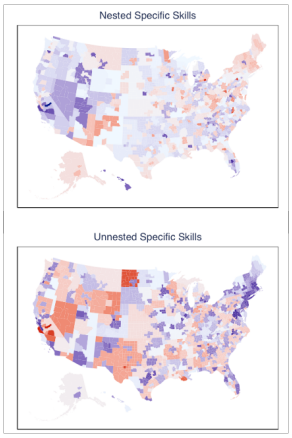
Disparity distribution of skills in Demographic variables





Application: Geographic Distribution of Skills





Thank You!

Moh Hosseinioun

University of Illinois at Chicago

Kellogg School of Management

Northwestern Institute on Complex Systems at Northwestern

Frank Neffke

Complexity Science Hub Vienna

Growth Lab and Center for International Development at Harvard University

Letian Zhang

Harvard Business School