

Who Becomes an Inventor?: The (Important) Role of Knowledge Absorption from Higher Technical Education

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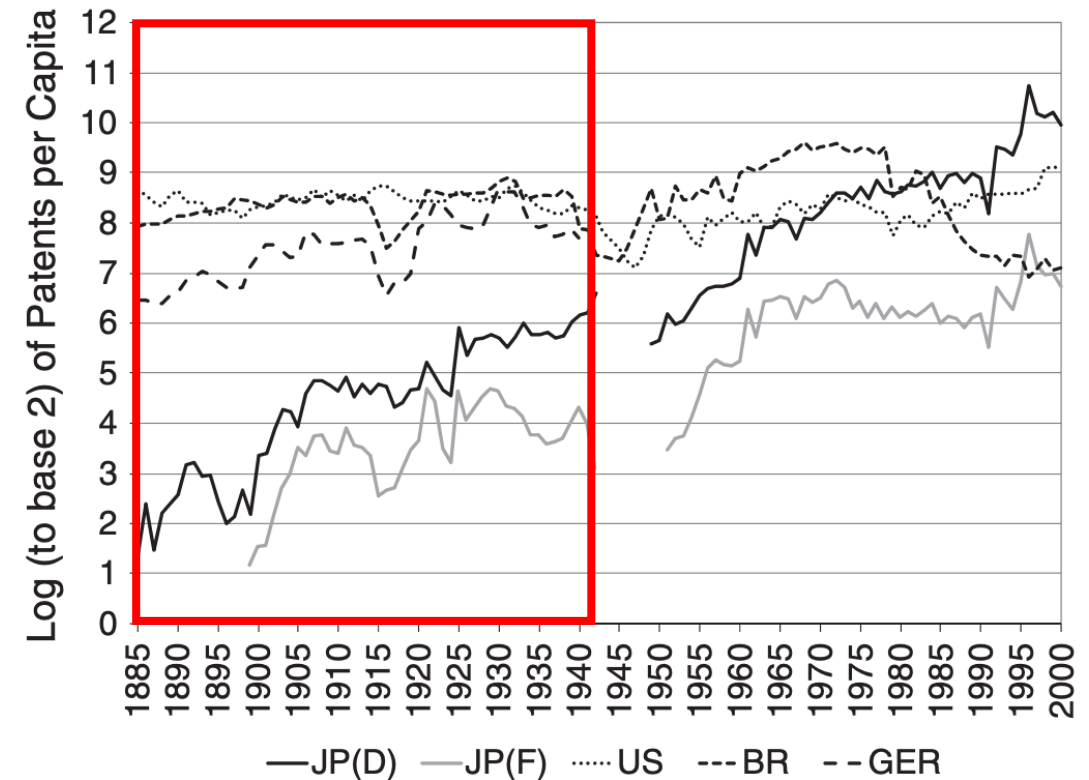
Presented at Japan Economic Seminar

February 20, 2026



Japan's Experience During Early Industrialization: From Absorbing Foreign Technology to Original Innovation

- At the onset of industrialization, “borrowed technology” to support industrial development.
- Over time, however, domestic invention increased sharply, particularly after World War I and especially in technological domains central to the Second Industrial Revolution (Nicholas, 2011).



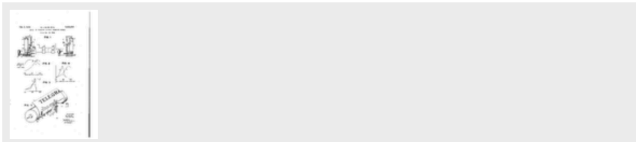
Globally Relevant Invention Already in 1917

- **Kazue Akashi** (明石和衛),
 - College of Engineering, Tokyo Imperial University, Mechanical Engineering graduate (1913)
 - Japan Patent #30943, 1917, Solid Ink 固形「インキ」
 - U.K. Patent #114601 (1919), U.S. Patent #1325971 (1919): 43 citations up to the present day



Means for producing facsimile telegraph signals

Images (1)



Classifications

H04N1/23 Reproducing arrangements

US2435223A

United States

Download PDF Find Prior Art Similar

Inventor: Bernard L Kline, Robert W Harris

Current Assignee: Western Union Telegraph Co

Worldwide applications

1944 - US

Zinc-complex photoinitiators and applications therefor

Abstract

The present invention is directed to energy-efficient, photoinitiators having the general formula: wherein Z each independently represent wherein R1, R2, R3, R4, R5, R6, R7, R8 are as defined in claim 1, and wherein R9 represents (R10)2O or (R10)3N; wherein R10 represents H or an alkyl group having from one to eight carbon atoms; and wherein R11 represents H, an alkyl group having from one to eight carbon atoms, a benzyl group or an aralkyl group. The present invention is also directed to a method of generating a reactive species, methods of polymerizing polymerizable materials, methods of curing an unsaturated oligomer/monomer mixture, and methods of laminating using the photoinitiators of the present invention. In addition, the present invention is directed to ink compositions, adhesive compositions and resins, and methods of printing using the above-described photoinitiators.

Classifications

US6486227B2

United States

Download PDF Find Prior Art Similar

Inventor: Ronald Sinclair Nohr, John G. MacDonald

Current Assignee: Mind Fusion LLC

Worldwide applications

2001 - CA US MX EP JP AT KR DE AU WO

Patent Citations (4)

Publication number	Priority date	Publication date	Assignee	Title
US1325971A *		1919-12-23		Kazue akashi
US2138836A *	1935-01-24	1938-12-06	Ditto Inc	Material for transfer processes
US2172465A *	1931-11-20	1939-09-12	Celluloid Corp	Ink for transparent projection strips
US2351231A *	1942-07-03	1944-06-13	Western Union Telegraph Co	Automatic facsimile telegraph system

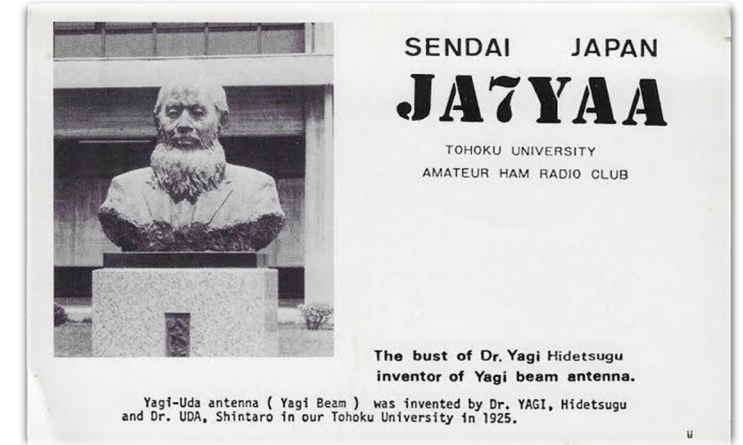
Family To Family Citations

Patent Citations (360)

Publication number	Priority date	Publication date	Assignee	Title
US282225A		1860-05-08		Improvement in apparatus for defecating cane-juice
US28789A		1860-06-19		Boiler foe
CA93103A	1905-04-18	1905-05-16	George Nickel	Elevator bucket
US1013544A	1910-08-30	1912-01-02	Equilibrator Company	Ink.
US1325971A		1919-12-23		Kazue akashi
US1364406A	1920-04-24	1921-01-04	Chester Novelty Company Inc	Ink-stick
GB355686A	1929-06-08	1931-08-26	Kodak Ltd	Improvements in or relating to combined kinematographic and sound record films

Yagi Antenna (1925)

- **Hidetsugu Yagi** (八木秀次): One of Japan's 10 Greatest Inventors
 - College of Engineering, Tokyo Imperial University, Electrical Engineering graduate (1909)
 - Japan Patent #69115, 1925,
 - Variable directional electric wave generating device (電波指向方式)
 - U.S. Patent #1860123, 185 citations
 - Why are Yagi antennas popular? There are many reasons:
 - You can easily calculate out the necessary dimensions for the antenna, even though the underlying electromagnetic analysis is complicated.
 - Any adjustments to these dimensions to accommodate practical issues such thickness of the elements and end-fringe effects are well known and can be factored into the sizing analysis.
 - It is easy to build and compatible with DIY projects; the boom can be metal or even wood.
- (<https://www.5gtechnologyworld.com/demonstrating-antenna-diversity-part-3-the-yagi-antenna/>)



How Did This Come About?

The Role of Higher Technical Education

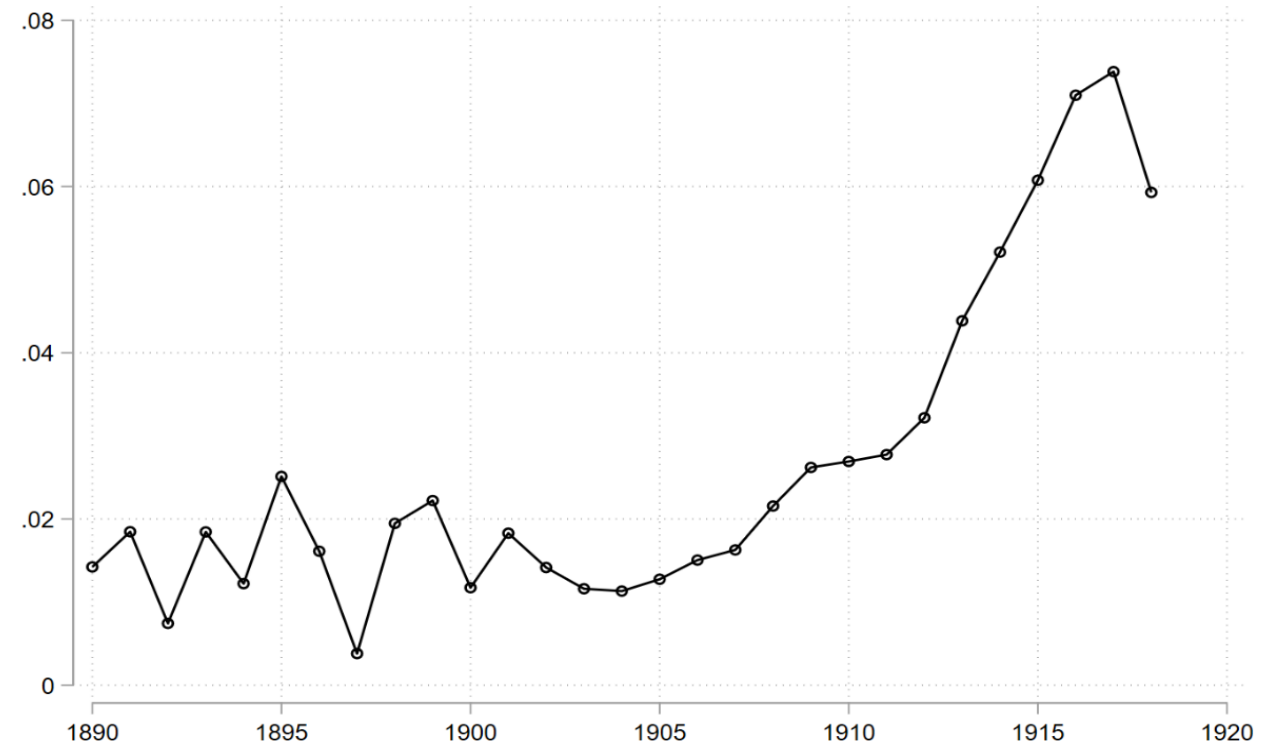
- No higher science or technical education prior to Meiji Restoration
- Meiji government negotiated for the team of Scottish engineering teachers (Henry Dyer) to come to Japan
- Educated cadres required to absorb and implement codified knowledge (Juhasz, Sakabe, Weinstein, 2024)
 - Imperial College of Engineering (工部大学校) opened in 1877
 - Merged into **Tokyo Imperial University** (東京帝国大学) in 1886
 - All education initially in English by foreign teachers



Educated Engineers Increasingly Important among Inventors

- Share in all patents, including those by foreigners
- Mokyr: “[I]t is undeniable that technological progress during the Industrial Revolution was an elite phenomenon, carried ... by the thousands of trained engineers ... on whose shoulders the inventors could stand.”
- “Technological advance in the period of the Industrial Revolution was a minority affair; [b]ut the dynamics of competition are such that in the long run the few drag along the many.”

Share of patents by University-educated inventors in total



Educated Engineers Increasingly Important among Inventors

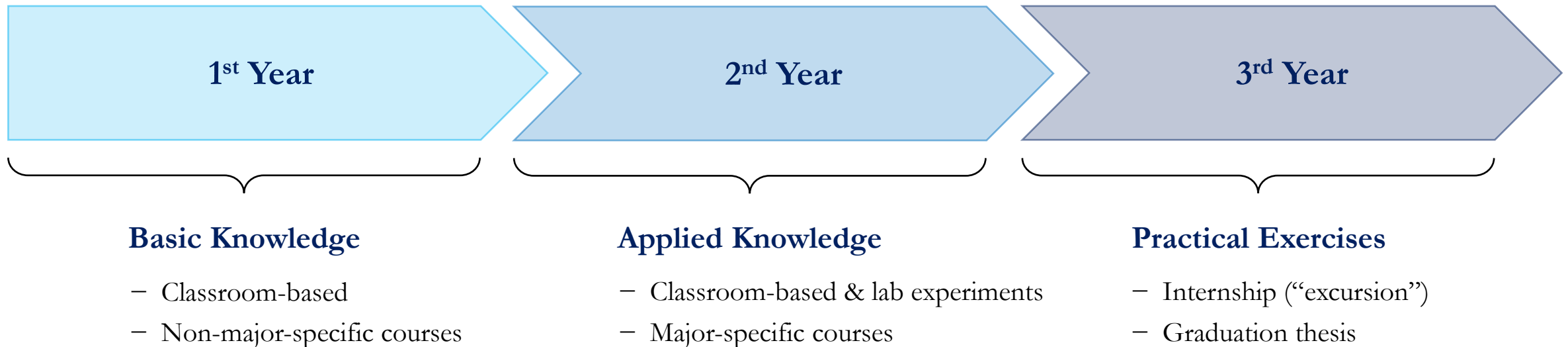
- **BUT: How exactly does education make people more likely to become inventors?**
 - Prior studies mostly looking at education vs. no education, years of schooling, attained degrees, etc.
 - Still, even within the same educational attainment the outcomes are very different

Our Research Question: “Who among highly educated people become inventors?”

1. **What type of knowledge** absorbed through S&E education matters?
 2. **Does it matter how well people absorb** what they had been taught in S&E education?
- Is there a *direct* effect of university education?
 - Separated from general ability or family backgrounds
 - Separated from job sorting or additional educational opportunities (e.g., studying abroad)
 - Relationship between types of educational training and types of patents?

What We Do: Use Education Curriculum in Imperial University

- Different types of knowledge taught in each year

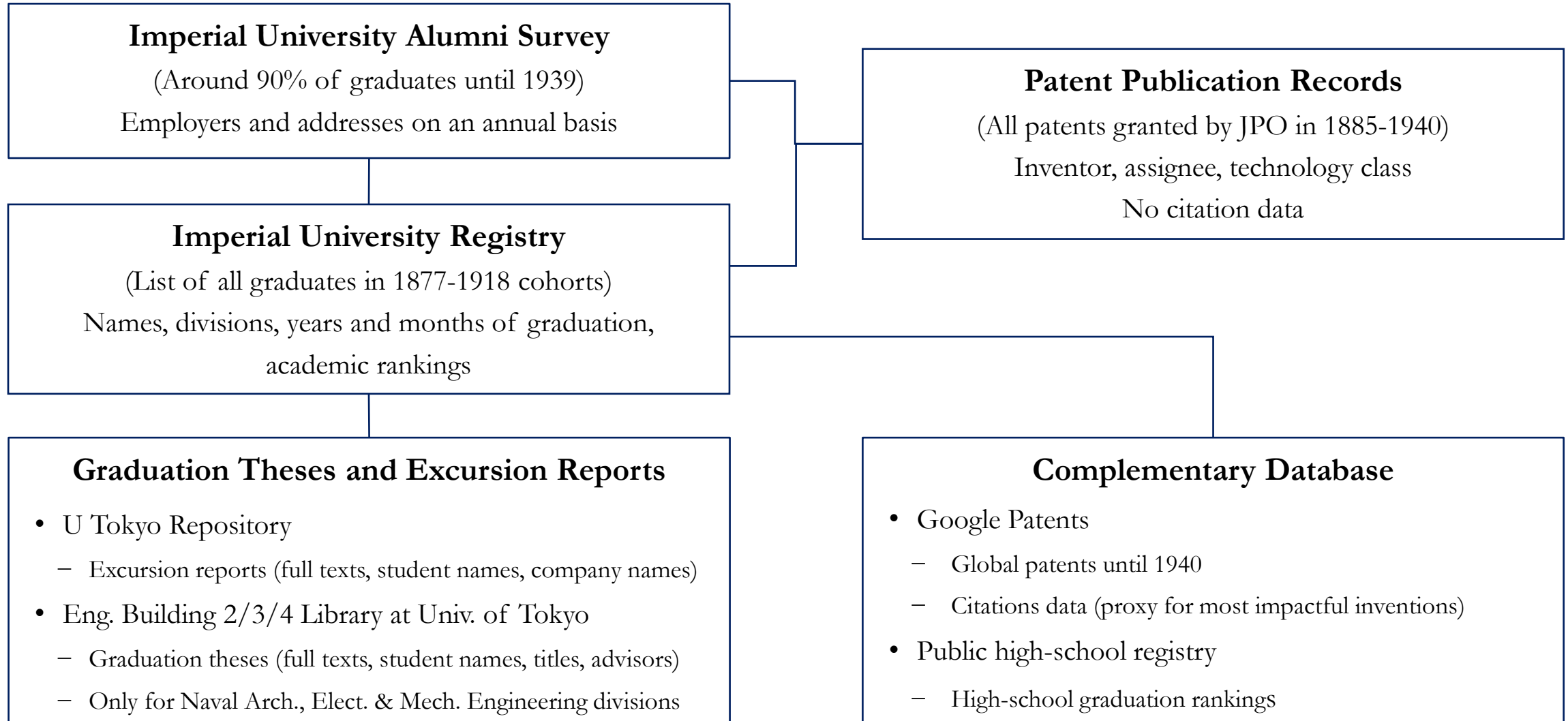


- Students listed in the **rank-order** of academic performance (席次) **in each year in the program**
- Use these rank-orders as a measure of academic achievement (knowledge absorption) relative to peers in the same division and cohort and distinguish the effects of absorption of different types of knowledge taught in each year
- Also, high-school graduation rankings as a measure of general academic ability

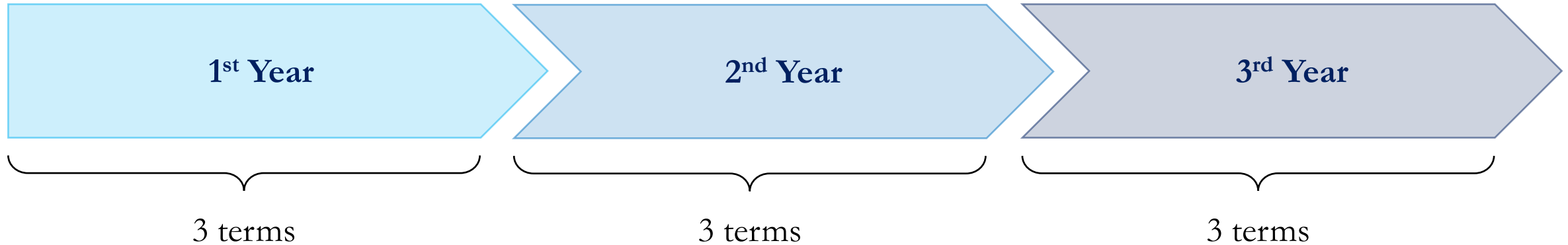
Preview of Main Findings

1. The **proficiency in practical engineering training** is of first-order importance for future inventions
 - Classroom knowledge is important but when **integrated with practical engineering training**
 - The **proficiency in classroom knowledge** is, however, more relevant for globally patented inventions
 - Globally relevant inventions need more scientific knowledge codification
2. The **effect of knowledge absorption is (at least partially) causal**
 - Graduates may have inventive ability prior to entering the university, correlated with academic achievement
 - Conceivably, might have even already nurtured abilities to invent *in specific technology areas* (Bell et al, 2019)
 - BUT: direction-specific endogeneity concern seems farther-fetched in the case of students' graduation theses.
 - Even in the case where there is sorting by general or even division-related inventive ability at enrollment, must be combined with specific knowledge absorbed in the university
3. While job sorting based on academic performance is an important mediator, **almost half of the effect was direct** or mediated by unmeasured factors
 - Higher performers in S&E education were more likely to become inventors:
 - After studying abroad in post-graduation periods
 - While working in research institutions
 - Much of the effect of academic performance remain even after controlling for unobserved organization factors

Data Structure



Education Curriculum in Imperial University



- The curriculum at Tokyo Imperial University College of Engineering followed a three-year structure
 - There were three terms in each year
- There were nine divisions in the Engineering Department



Civil Engineering



Mechanical Engineering



Naval Architecture



Electrical Engineering



Architecture



Applied Chemistry



Metal and Mining

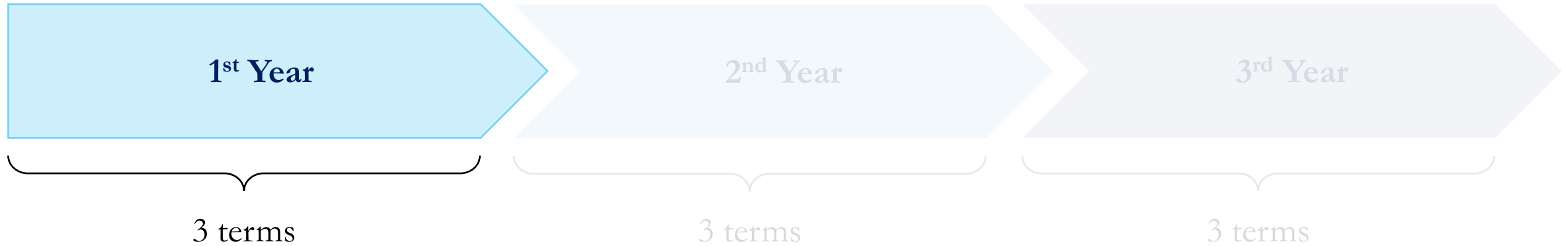


Ordnance

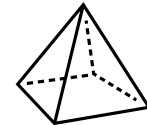
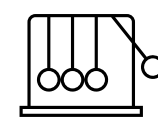
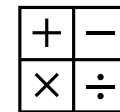


Explosive

Education Curriculum in Imperial University



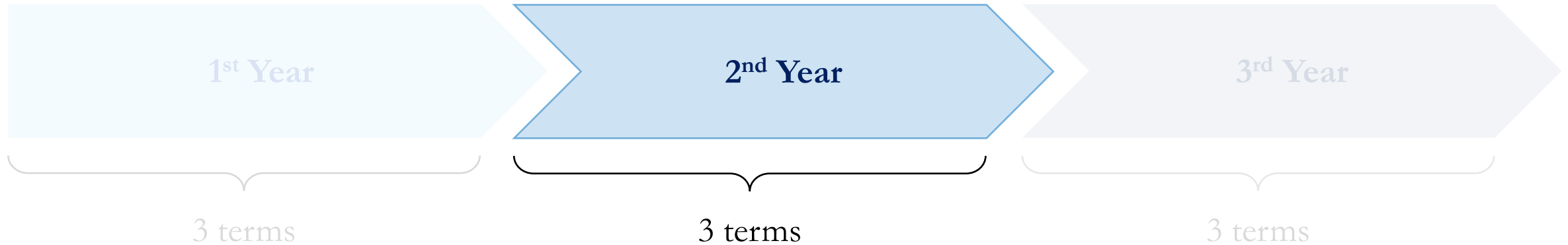
- Most of the first two years were dedicated to **classroom-based coursework**
- In the first year, students mostly learned **basic (fundamental) subjects**
 - E.g., mathematics, physics, mechanics, dynamics, hydraulics



Ex. 1st-Year Courses in Mech. Eng. Division

First Year	Hours per Week		
	1st Term	2nd term	3rd Term
<u>Required Subjects</u>			
Mathematics	3	3	-
Dynamics	1	1	1
Applied Mechanics	3	3	2
Heat and Heat Engines	3	2	3
Mechanism	1	1	1
Hydraulics	-	2	2
Mechanical Technology	1	2	2
Machine Design and Materials	2	2	2
Electrical Engineering	2	2	2
Exercises in Applied Mechanics	3	3	3
Physical Laboratory	3	3	3
Workshop Practice	3	3	3
Design and Drawing	14	10	15

Education Curriculum in Imperial University



- Most of the first two years were dedicated to **classroom-based coursework**
- In the second year, the students progressed to **more advanced and applied courses** tailored to specific majors
 - “Hydraulic machinery” in mechanical engineering
 - “Stability and rolling of ships” in naval architecture
- They were required to spend more time performing **experiments in laboratories**
 - Often in the third year too

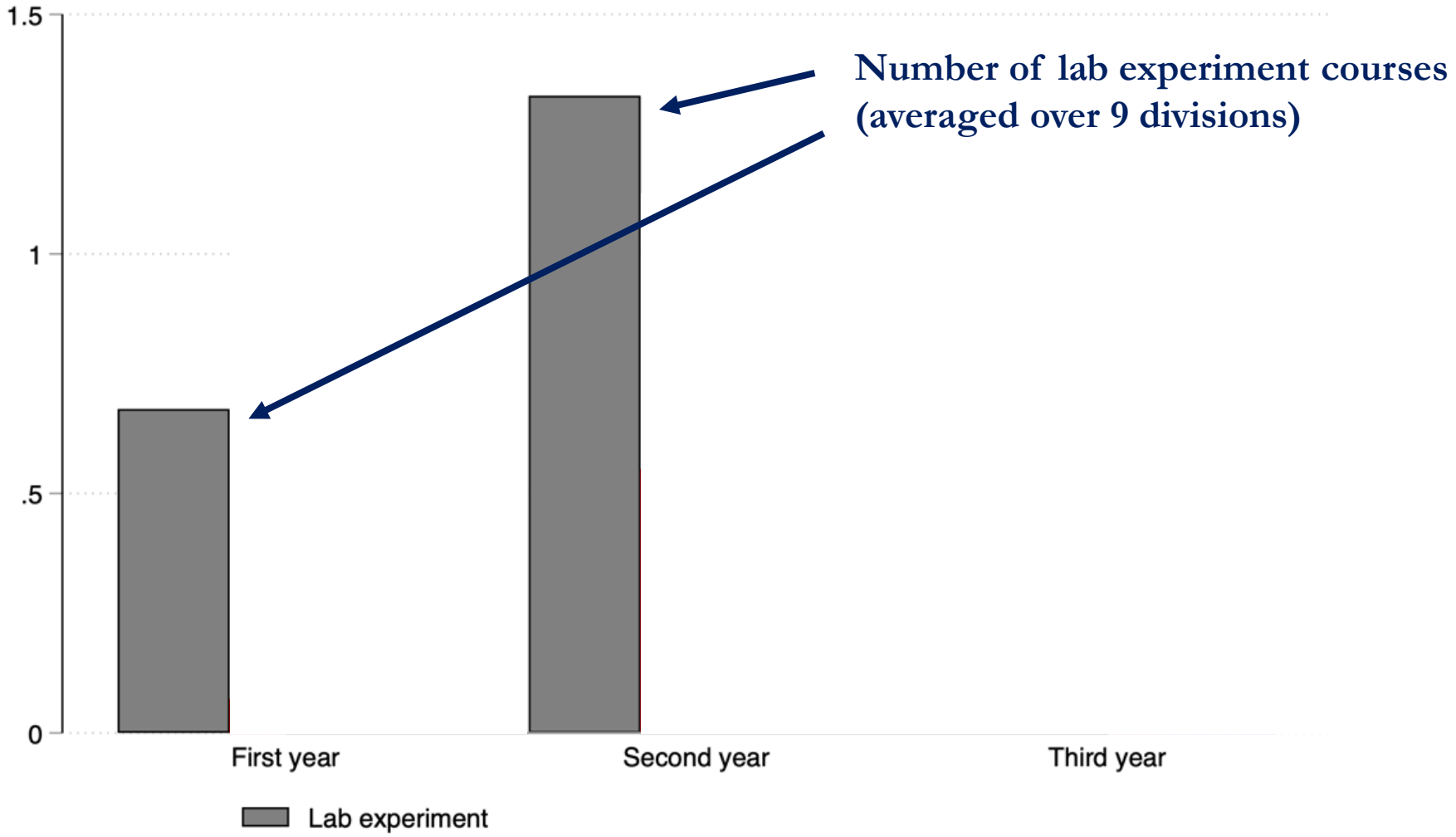


Ex. 2nd-Year Courses in Mech. Eng. Division

Second Year	Hours per Week		
	1st Term	2nd term	3rd Term
<u>Required Subjects</u>			
Thermodynamics and Heat Engines	3	3	3
Dynamics of Machinery	1	1	1
Hydraulic Machinery	1.5	2	2
Electrical Engineering	2	2	2
Testing of Electrical Machines	1	1	1
Metallic Materials and Metallurgical Technology	3	2	2
Building Construction	2	2	-
Machine Design	2	1	-
Industrial Economy	1.5	1.5	1.5
Experimental Engineering	1	1	1
Mechanical Engineering Laboratory	3	3	3
Design and Drawing	12	12	15
Electrical Engineering Laboratory	-	3	3

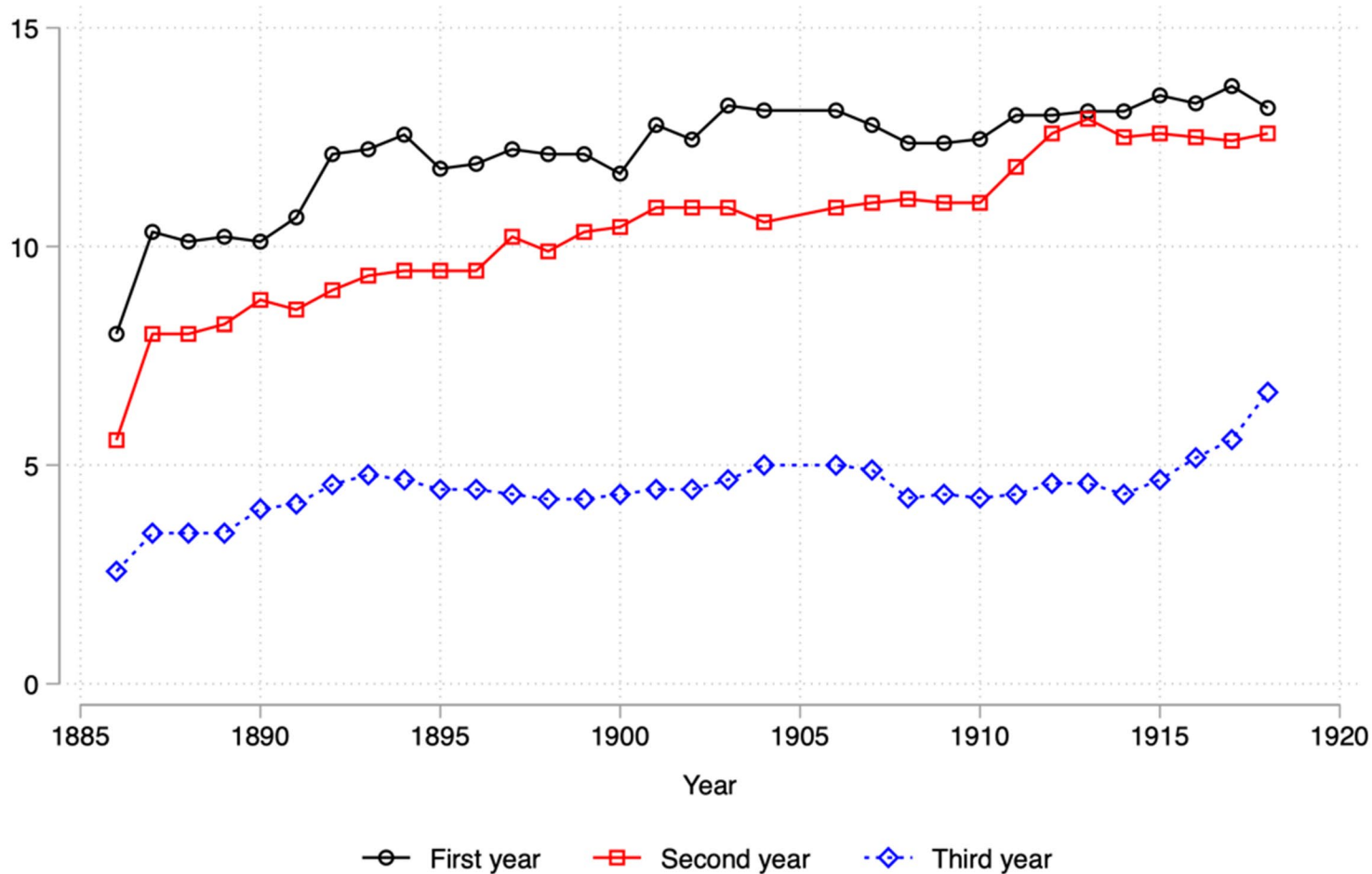
- Students were also required to take one elective course

More Laboratory Experiments in 2nd Year



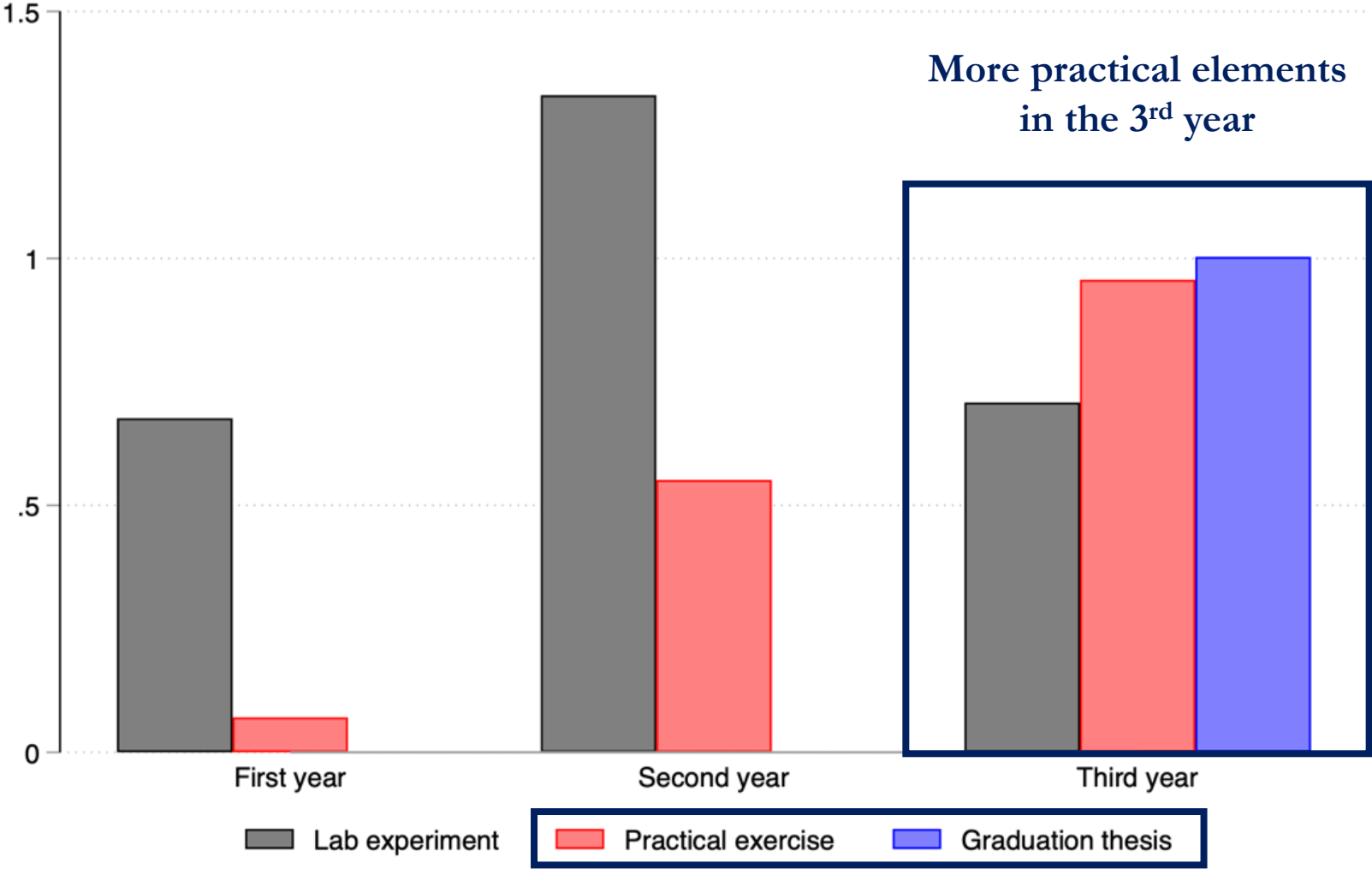
Education Curriculum in Imperial University

Average Number of Required Courses by Year in the Program



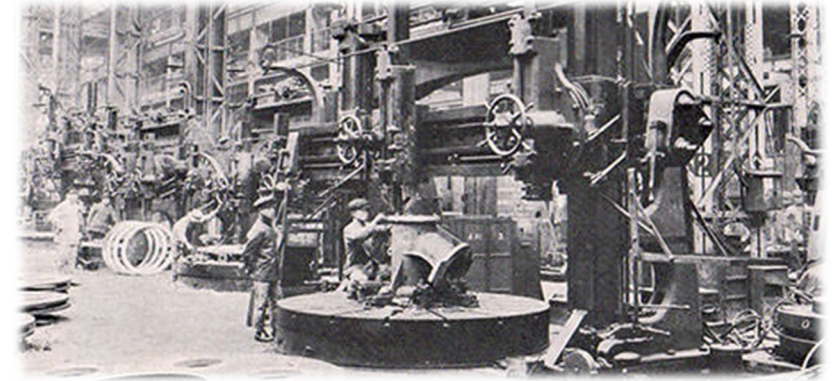
- The number of hours in the classroom was drastically reduced
 - Less than half of the number of the courses in the 1st/2nd years
- What did they do?

More Practical Courses in 3rd Year



“Excursion” (Practical Training)

- In the third year, students need to take a course called “practical exercise”
 - This practical training was done either at the university or outside (**internship**) at private companies or government institutions
- The internship often lasted up to half a year or more
 - It was called an “**excursion**”



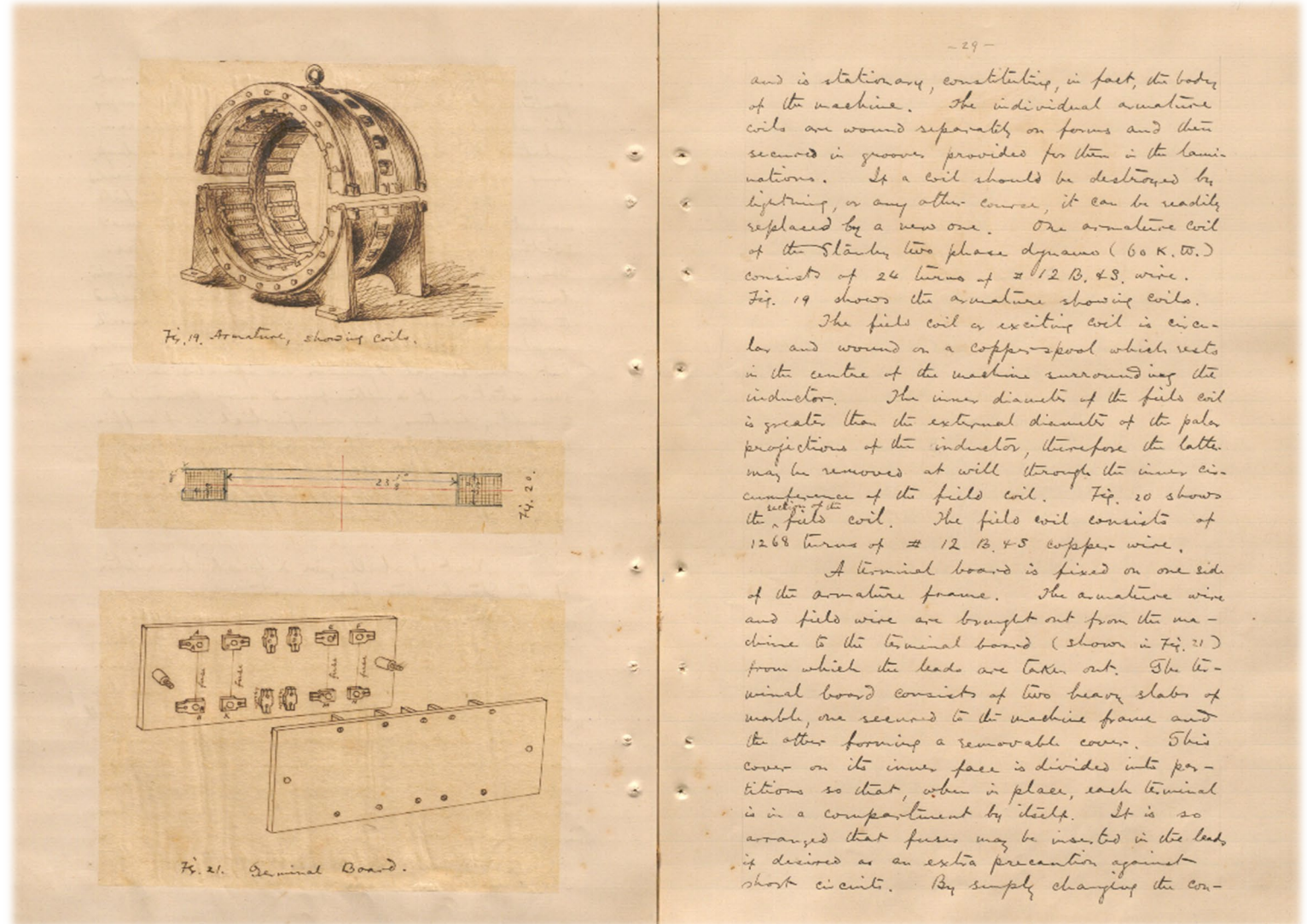
Regulation relating to practical training

- Purpose of practical training
 - “The object of practical training is to make students acquainted with the **practical application of scientific principles**, and for this purpose students shall be **trained in practical work or sent out to see various establishments or institutions of industry** relating to their respective studies”
- Guided by university faculty, even if students make excursions
 - “Students shall from time to time **obtain directions for their work from the professor in charge**, but when they by themselves undertake practical work outside the college, or make an excursion, they must previously receive directions from the professor
- Students were required to “**make out a report of their work** and submit it to the professor in charge”

A Sample of Excursion Report

Keijiro Kishi (1869-1927)

- Future Chief Engineer in Shibaura Seisakusho (Toshiba)
- Went to Shibaura Seisakusho for practical exercise



A Sample of Graduation Thesis

- 14 -

small. If we represent the mean secondary $\epsilon.m.f.$, $\frac{E_2}{\sqrt{2}}$ by \bar{E}_2 , we have

$$T = \frac{K s_2 \bar{E}_2^2}{(\rho_1 - \rho_2) R_2} \quad \text{--- (11)}$$

The output of the motor in watts, which we represent by W , is

$$W = \frac{\rho_2}{K} T$$

$$\text{or } W = \frac{s_2 \bar{E}_2^2}{R_2} \frac{\rho_2}{(\rho_1 - \rho_2)} \quad \text{--- (11a)}$$

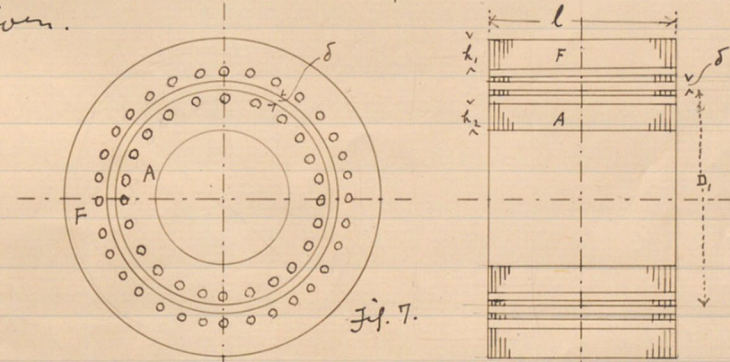
Letting v represent the slip, so that, for instance, for two per cent. slip $v = 0.02$, we shall have

$$\rho_2 = \rho_1 (1 - v) \quad \text{--- (12)}$$

$$\text{and } W = \frac{s_2 \bar{E}_2^2}{R_2} \left(\frac{1}{v} - 1 \right) \quad \text{--- (13)}$$

and $W = R_2 \dots$

The secondary $\epsilon.m.f.$, E_2 , can be easily found from the dimensions and winding of the motor when the primary $\epsilon.m.f.$ is given.

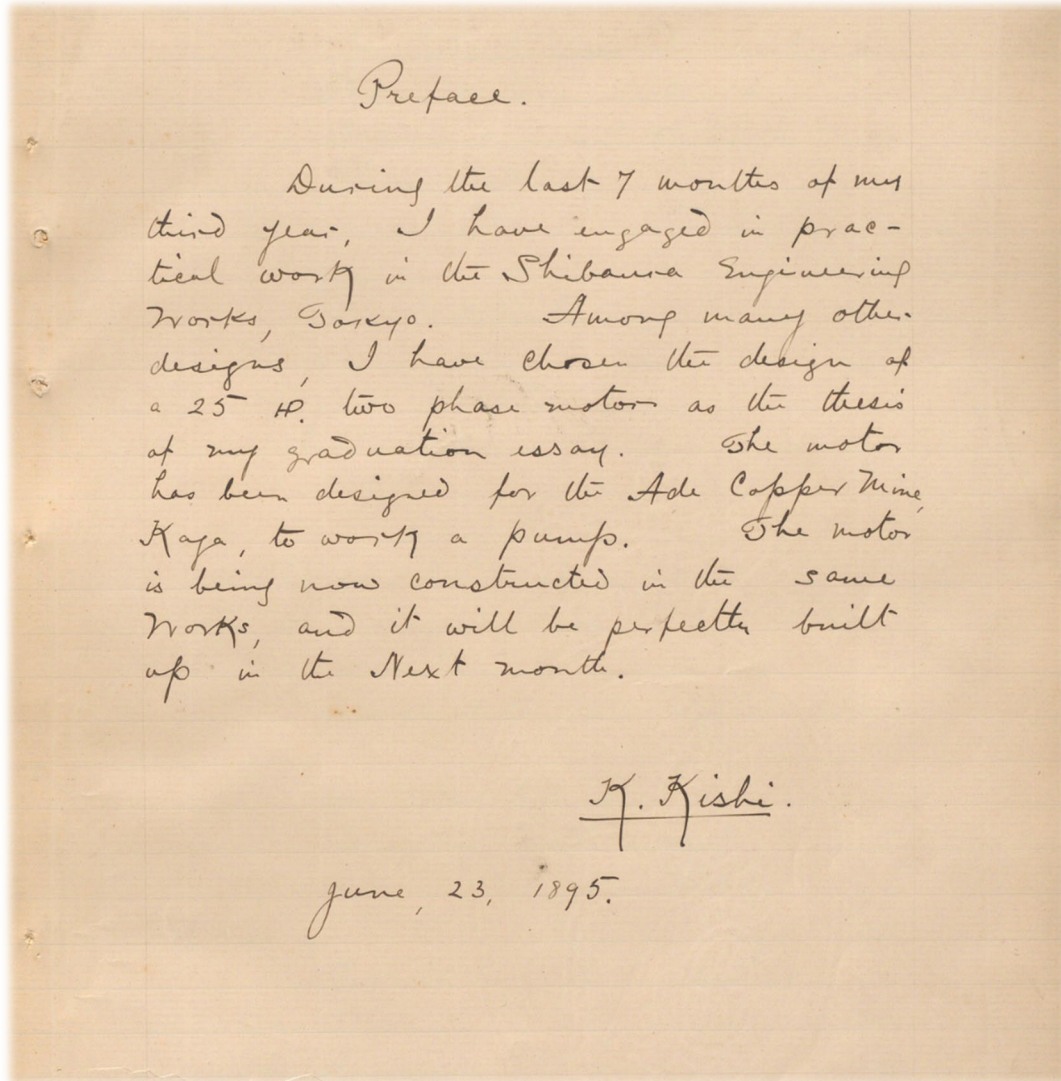


In Fig. 7, F represents the iron core of the field and A that of the armature.

Let B_g , be the intensity of the rotating field per sq. centimeter in the air space δ (Fig. 7);

Kishi's graduation thesis: "The Calculations of Multi Phase Motors, with a Design of a 25HP Two Phase Motor"

Kishi's Graduation Thesis



Preface

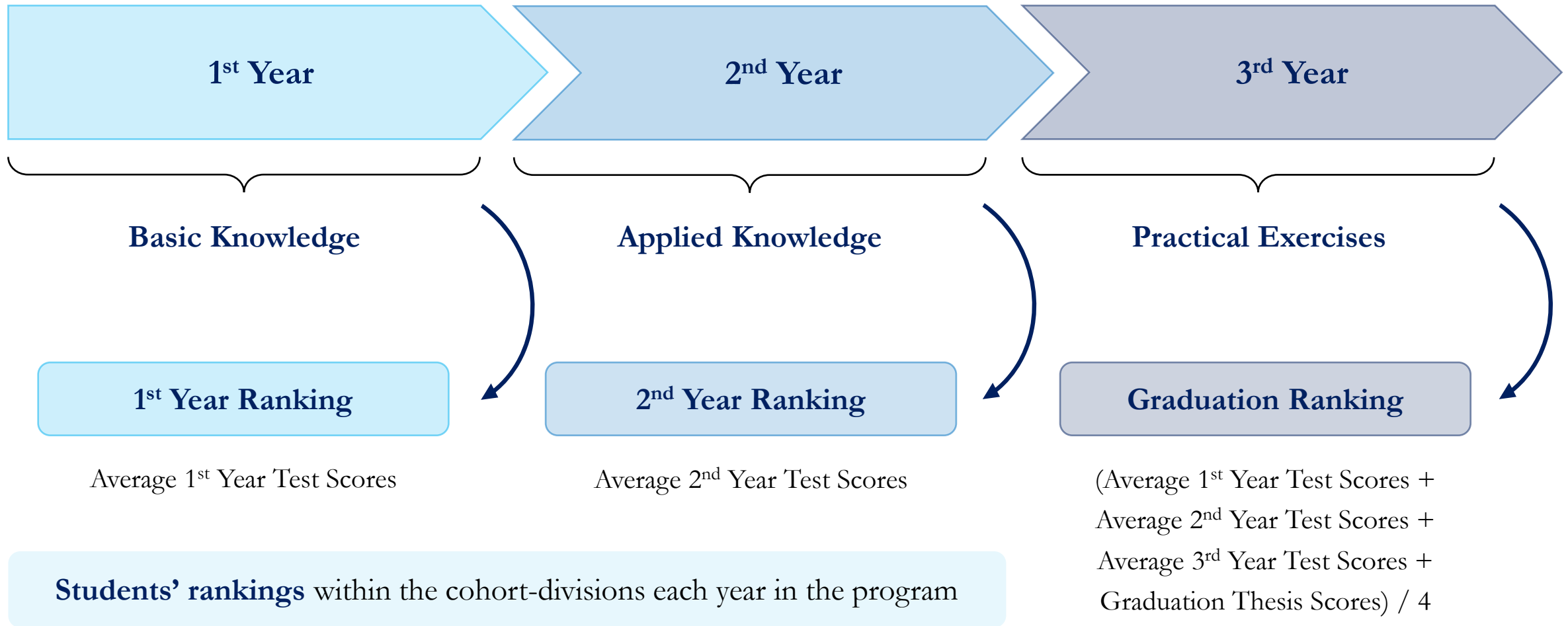
*During the last 7 months of my third year, I have engaged in practical work in the **Shibaura Engineering Works (Toshiba)**, Tokyo. Among many other designs, I have chosen the design of a **25 HP two phase motor** as the thesis of my graduation essay. The motor has been designed for the Ade Copper Mine, Kaga, to work a pump. The motor is being now constructed in the same works, and it will be perfectly built up in the next month.*

K. Kishi

June 23, 1895

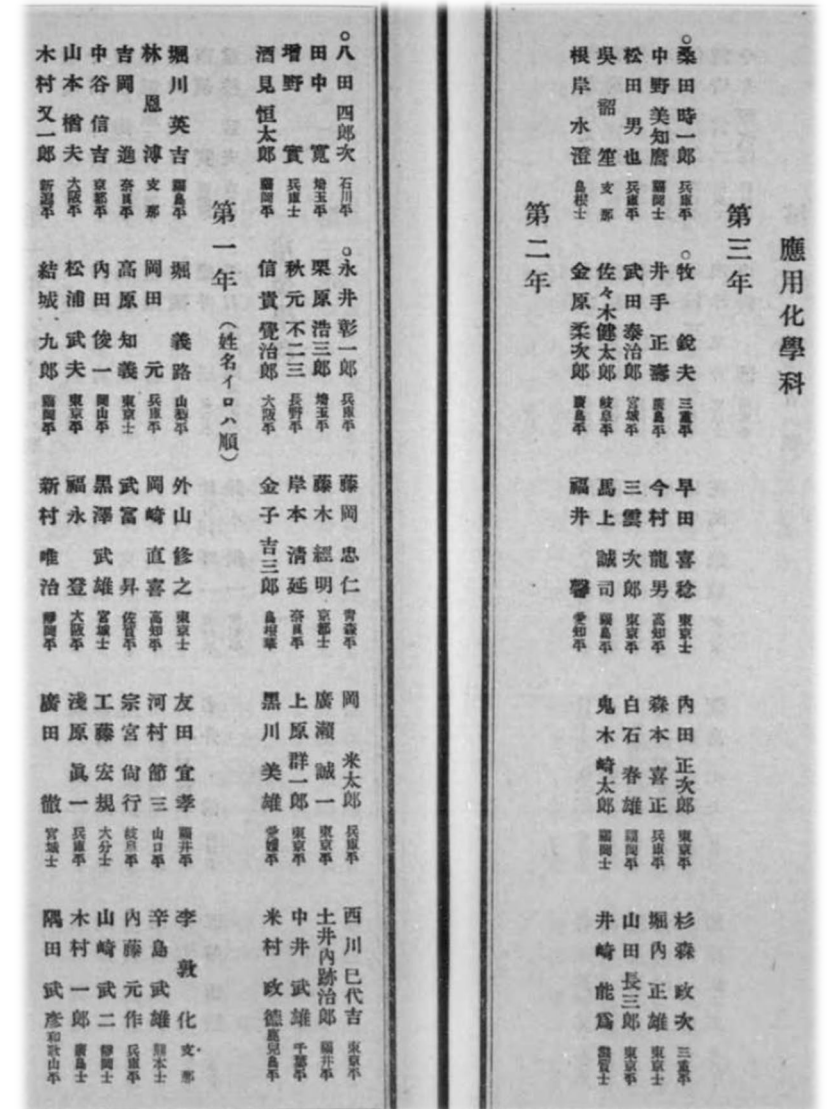
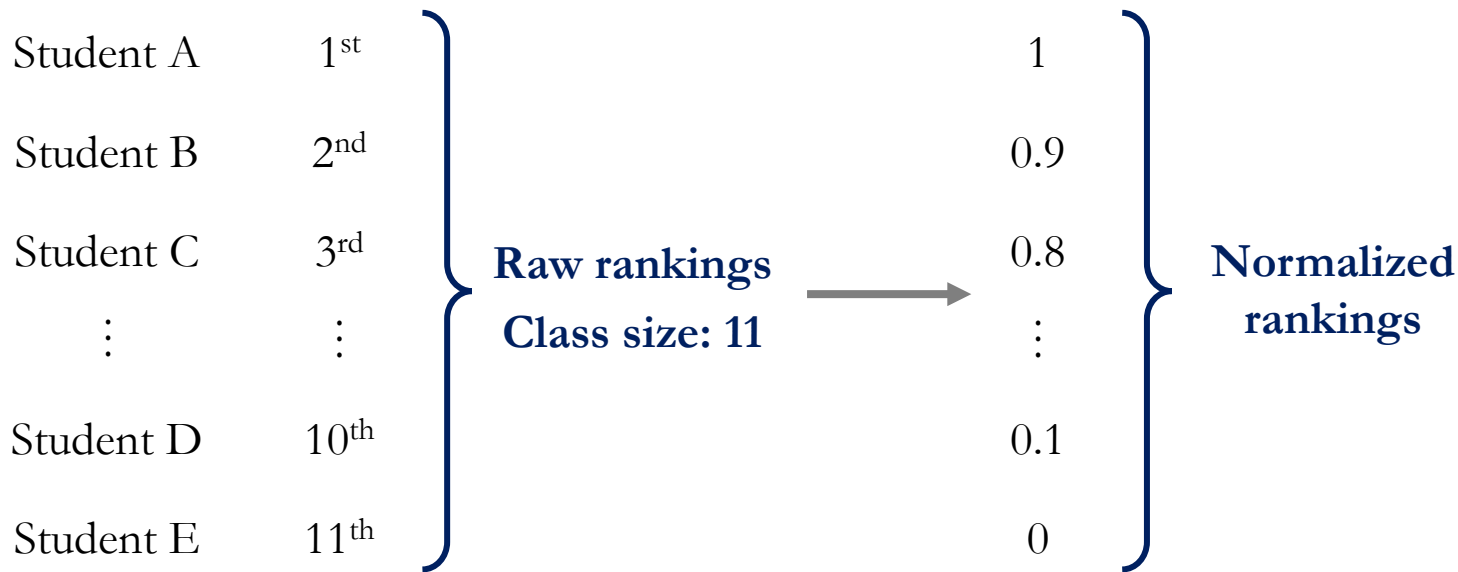
- Some of the thesis were inspired by their observations, works, and experiences in excursion

Evaluation in the Program

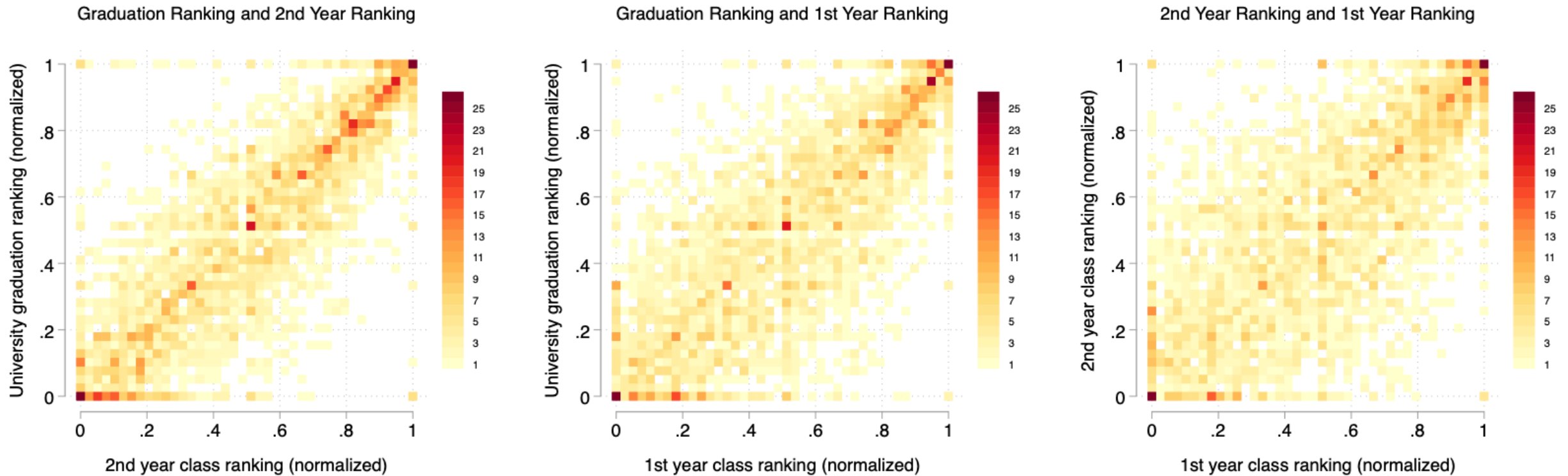


Academic Rankings

- Students were listed in the order of rankings within each division-cohort
 - At the beginning of 2nd year and 3rd year, and when they graduate
- To make rankings comparable across cohorts and divisions, we **normalize** them by range **from zero** (the lowest) **to one** (the highest)
- High-school graduation rankings are also recorded in the same way



Joint Distribution of Academic Rankings



Inventors

- Inventor = graduates who were granted at least one patent within 20 years after graduation
 - Among 3,796 graduates until the 1918 cohort, 578 (15%) were inventors (81 of those were also global patent holders)
- The number of inventors grew, but the fraction of inventors among graduates was stable over time around 10-18%
- Technology-oriented divisions have many inventors
 - Mechanical engineering, electrical engineering, and applied chemistry

Number of inventor by graduation division

	Division Graduated From							
	Civil Engineering	Mechanical Engineering	Naval Architecture	Electric Engineering	Architecture	Applied Chemistry	Metal and Mining	Others
Non-Inventors	792 (95.54)	665 (81.10)	324 (90.76)	419 (75.50)	236 (92.55)	223 (62.46)	471 (90.40)	83 (85.29)
Inventors	37 (4.46)	155 (18.90)	33 (9.24)	136 (24.50)	19 (7.45)	134 (37.54)	50 (9.60)	19 (18.63)
Total	829	820	357	555	255	357	521	102

Main Specification

- Main Empirical Specification (Cross-section)

$$y_i = \sum_k \beta_k Acad_Perf_{k(i)i} + \underbrace{d_{c(i)d(i)} + d_{c(i)h(i)} + d_{g(i)}}_{\text{Fixed Effects}} + \varepsilon_i$$

y_i : Indicator for having at least one patent within 20 years after graduation

$k(i)$: Year in the program ... 1st, 2nd, 3rd (or graduation ranking) or high school

$c(i)$: Graduation cohort

$d(i)$: Graduation division

$h(i)$: High school

$g(i)$: Birthplace prefecture

⇒ How does the absorption of higher technical knowledge shape long-run inventive activities by graduates?


Academic Rankings and Inventions






Is This Really Knowledge Absorption or Something Else: Evidence from Division-Related Patents

- If knowledge absorbed through higher technical education contributes to patenting by graduates, **they are particularly likely to patent in the technology classes closely related to their graduation division**
- To examine this, we first create the bridge between patent classes in JPO and graduation divisions
 - Then categorize patents as division-related if patent classes in JPO match with individual graduation divisions

Examples:

Patent Class 23: Dyeing ———  Applied Chemistry

Patent Class 96: Telegraph and Telephone ———  Electrical Engineering

Patent Class 58: Power Transmission ———  Mechanical Engineering  Electrical Engineering

Patent Class 85: Ship and Submarine Vessel ———  Mechanical Engineering  Naval Architecture

Division-Related Inventions



Is This Really Knowledge Absorption or Something Else: Evidence from Thesis-Related Patents

- If knowledge absorbed through higher technical education contributes to patenting by graduates, **they are particularly likely to patent in the technology classes closely related to their graduation thesis**
- To measure the similarity between patents and themes of graduation theses, we use **text similarity** (SBERT) (Reimers and Gurevych, 2020)
 - Map patent characteristics (titles, classes, categories, and sub-categories) and the titles of graduation theses to a 384-dimensional vector space by SBERT pre-trained models, taking the meanings of the sentences into account
 - Given the vector representations, we calculate the cosine similarity between patent characteristics and the titles of thesis

Examples of Text Similarity

Hideichi Oana (Electrical Engineering) ... Title of graduation thesis: **Essay on The Phase Control by Means of Synchronous Motor**

Patent characteristics	Title	Class	Category	Sub-category
		Synchronous motor	Generators, electric motors	Generators, electric motors
Cosine similarity	0.809	0.444	0.444	0.603

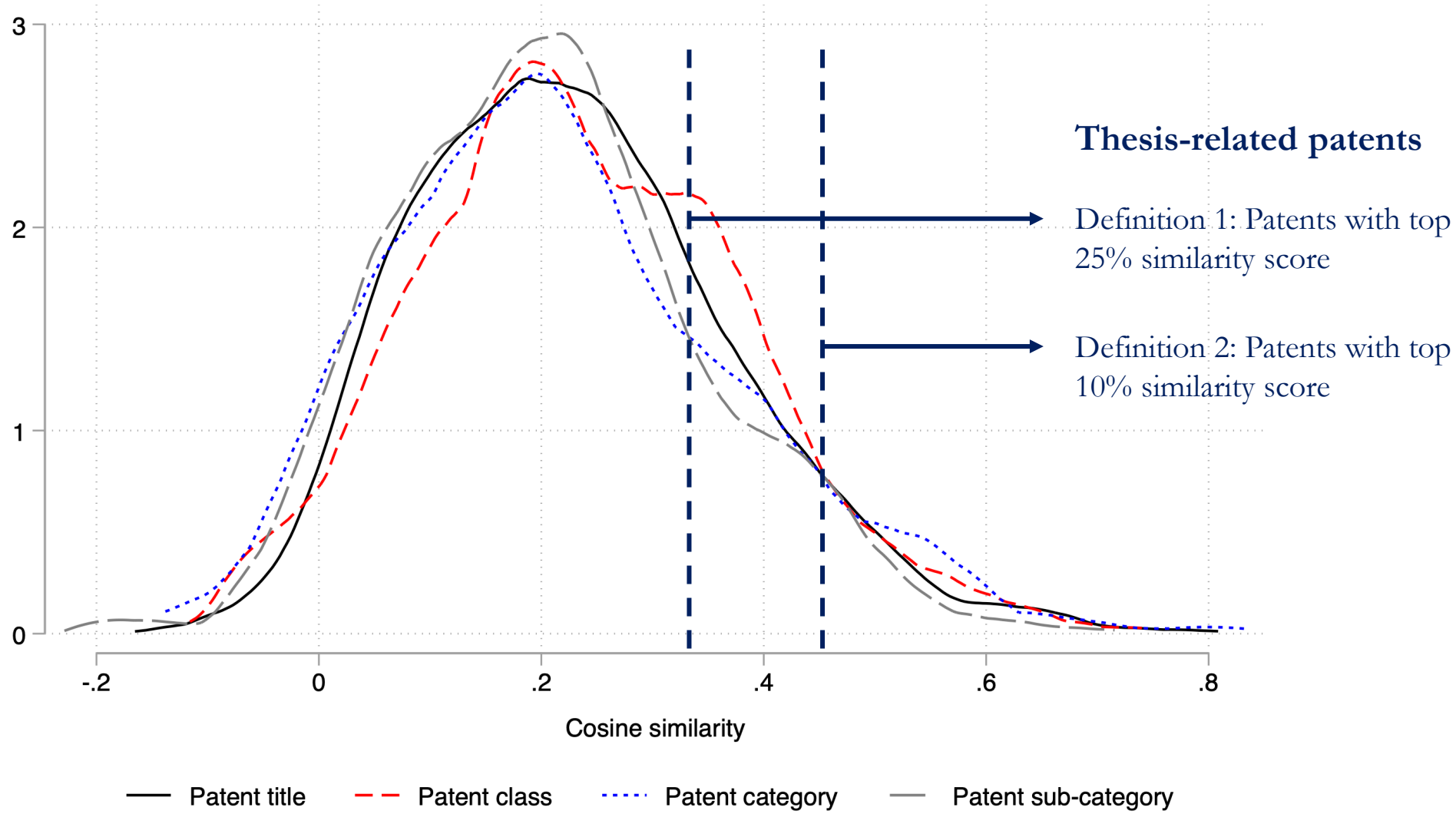
Koroku Wada (Naval Architecture) ... Title of graduation thesis: **Stability of Aeroplane**

Patent characteristics	Title	Class	Category	Sub-category
		Airplane wing performance improvement device	Aviation	Common structure of planes
Cosine similarity	0.654	0.640	0.681	0.456

Seiyu Soga (Naval Architecture) ... Title of graduation thesis: **About Transverse Strength of Ships**

Patent characteristics	Title	Class	Category	Sub-category
		Air separation devise	Nonmetallic elements	Nitrogen
Cosine similarity	0.224	0.227	0.062	0.082

Distributions of Text Similarity



Thesis-Related Inventions



Globally Important Inventions



Early vs. Late Inventions

Early: invention within 12 years after graduation

Late: otherwise (12 is median year of the first inventions)



Does Academic Performance Contribute to Patenting, Independently of Firm-Level Factors?

- Applying the AKM model (Abowd et al., 1999)
 - Captures the effect of *time-invariant, individual-level* factor (i.e., academic performance)
- Outcome model: $y_{it} = X'_{it}\gamma + f_i + f_t + f_e + \eta_{it}$
 - y_{it} : a dummy for an individual i 's patent application in year t
 - X'_{it} : time-varying firm-level characteristics (research-related job; affiliated with zaibatsu conglomerates; high-tech industry)
 - f_i, f_t, f_e : individual-, year-, employer-fixed effects.
- $f_i = \sum_k \beta_k Acad_Perf_{k(i)i} + d_{c(i)d(i)} + d_{c(i)h(i)} + d_{g(i)} + \varepsilon_i$
 - $Acad_Perf_{k(i)i}$: a student i 's rank at each stage
 - $d_{c(i)d(i)}, d_{c(i)h(i)}, d_{g(i)}$: cohort-division-, cohort-high-school-, and birthplace-fixed effects

→ Obtain the estimates of individual-fixed effects

Firm-Level Factors and Study Abroad DO Matter

Table 5. Panel-Data Estimation of the Probability of Invention

	(1)	(2)	(3)	(4)	(5)	(6)
1(research-related job)	0.0237*** (0.00846)				0.0233*** (0.00819)	0.0165* (0.00846)
1(firm affiliated with a <i>zaibatsu</i>)		0.00437 (0.00594)			0.000548 (0.00589)	0.0134 (0.0309)
1(firm in a high-tech industry)			0.0112*** (0.00338)		0.0104*** (0.00333)	0.0213*** (0.00597)
1(after study abroad)				0.0781*** (0.0105)	0.0779*** (0.0104)	0.0717*** (0.00956)
Mean of DV	0.0225	0.0225	0.0225	0.0225	0.0225	0.0226
Individual FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Employer FEs	No	No	No	No	No	Yes
Observations	56995	56995	56995	56995	56995	56793
Adj R-Squared	0.181	0.181	0.181	0.186	0.186	0.204

Still, the Effect of Graduation Rankings Remains

Table 6. Academic Performance and Individual Fixed-Effects from Table 5

	(1)	(2)	(3)	(4)	(5)	(6)
1st year class ranking	0.00239 (0.00704)	0.00246 (0.00705)	0.00154 (0.00701)	0.00152 (0.00687)	0.000616 (0.00677)	-0.000102 (0.00734)
2nd year class ranking	0.00564 (0.00740)	0.00586 (0.00738)	0.00549 (0.00735)	0.00271 (0.00708)	0.00231 (0.00705)	-0.00528 (0.00842)
University graduation ranking	0.0151* (0.00768)	0.0155** (0.00764)	0.0161** (0.00751)	0.0121 (0.00743)	0.0117 (0.00730)	0.0192** (0.00917)
High-school graduation ranking	0.00436 (0.00613)	0.00437 (0.00614)	0.00482 (0.00613)	0.00307 (0.00606)	0.00328 (0.00596)	0.00282 (0.00653)
Mean of DV	0.0201	0.0202	0.0182	0.0170	0.0136	0.00910
Division X cohort FEs	Yes	Yes	Yes	Yes	Yes	Yes
High-school X cohort FEs	Yes	Yes	Yes	Yes	Yes	Yes
Birthplace FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3087	3087	3087	3087	3087	3087
Adj R-Squared	0.0558	0.0603	0.0580	0.0266	0.0199	0.00173

Mediation Analysis

Outcome Specification

$$\begin{aligned}
 y_{ir} &= \kappa_0 + \kappa r + \underbrace{\sum_{j \in \mathcal{J}_p} \alpha_r^j \theta_{ir}^j}_{\text{measured mediators}} + \underbrace{\sum_{j \in \mathcal{J} \setminus \mathcal{J}_p} \alpha_r^j \theta_{ir}^j}_{\text{unmeasured mediators}} \\
 &\quad + d_{c(i)d(i)} + d_{c(i)h(i)} + d_{g(i)} + \tilde{\varepsilon}_{ir} \\
 &= \tau_r + \sum_{j \in \mathcal{J}_p} \alpha_r^j \theta_{ir}^j + d_{c(i)d(i)} + d_{c(i)h(i)} + d_{g(i)} + \varepsilon_{ir},
 \end{aligned}$$

Mediator Specification

$$\theta_{ir}^j = \mu_0^j + \mu_1^j r + d_{c(i)d(i)} + d_{c(i)h(i)} + d_{g(i)} + \eta_j$$

- We also include firm fixed effects as mediators

Effect Decomposition

$$\begin{aligned}
 E[y_{ir} - y_{ir'}] &= \tau(r - r') + \sum_{j \in \mathcal{J}_p} \alpha^j E[\theta_r^j - \theta_{r'}^j] \\
 &= \underbrace{\tau(r - r')}_{\text{DE \& UIE}} + \sum_{j \in \mathcal{J}_p} \underbrace{\alpha^j \mu_1^j (r - r')}_{\text{MIE}},
 \end{aligned}$$

DE : direct effect

UIE : unmeasured indirect effects

MIE : measured indirect effects

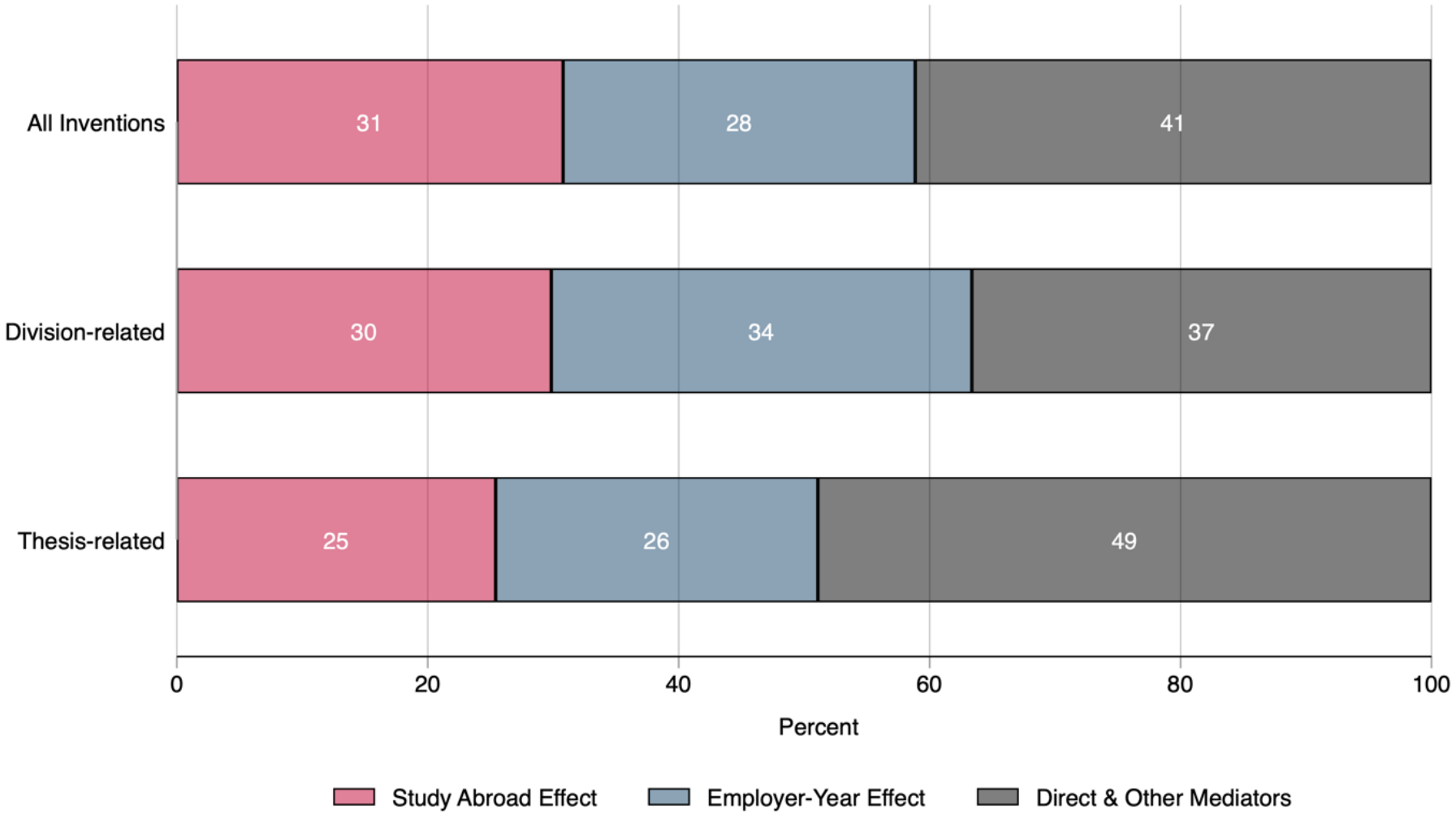
Main Idea

What fraction of the academic ranking effect on inventions can be explained by job sorting or opportunity to study abroad?



Decomposing the Effect of Graduation Rankings

(preliminary)



Direct S&E education effect and other individual-level mediators' effects are greater than employer effects

Conclusion

- The **absorption** of knowledge (measured by academic achievement) is crucial for future inventions
 - Students had received the same education, but better performance in the program (not necessarily innate ability) predicts becoming an inventor even after controlling for general academic ability
 - Complement the existing literature showing the importance of educational attainment
- Even though knowledge absorbed in the classroom is important, whether students can **integrate classroom knowledge with practical training** could be the main contributing factor predicting becoming an inventor
- While job sorting is an important mediator, **more than one third of the effect was direct** or mediated by unmeasured individual-level factors
 - Inventors' human capital does matter; particularly, developed through S&E education