Skills of Early-Career Workers:
Measurement and Labour-Market Returns

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Motivation 1/2

▶ **Individuals' skills** are important for their success on the labour market (e.g., Hanushek et al., 2015, 2017)

▶ However, **lack of suitable skill data**, in particular, on early-career skills

▶ Improved data on workers' skills would **enhance our understanding** of
  – occupational choices
  – career patterns
  – susceptibility to technological change

Motivation 2/2

Motivation: **Lack of suitable data** on workers' skills relevant on the labour market

▶ Most common skill measure is **years of schooling**
  − Broad variation in skills for each educational level

▶ Also widely used are **skill assessment data** (e.g., PIAAC, PISA)
  − Not designed to capture skills learnt or required at the workplace
  − Cover only a limited range of an individual's skill set
  − No natural unit of measurement

→ Both measures provide **only a crude approximation** of an individual's **actual range** of labour-market-relevant skills

What We Do

Skill Data:

► We use text data from **standardized apprenticeship plans** to construct **relevant, comprehensive, and detailed** measures of worker skills in Germany

► Unique German setting:
- **Same skills** are taught in an apprenticeship throughout Germany
- Apprenticeship plans also specify the **exact duration** apprentices learn a specific skill

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Empirical Approach:

► We link occupational skill intensities to **administrative labour-market records** to investigate **returns to skills** over workers' careers and over time

► We control for a rich set of **worker** and (apprenticeship) **establishment** characteristics, including apprenticeship fields

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Preview of Results:

► Cognitive, social & digital skills are **highly valued** throughout workers' careers

► **Pronounced increase** in returns to digital skills over the last three decades

Details

Institutional Setting

▶ German apprenticeship system

- About **60 percent of workers in Germany** have completed an apprenticeship
- Apprenticeship training is targeted at graduates from **lower or intermediate secondary schools**, typically start apprenticeship directly after school

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▶ Unique institutional setting for deriving measures of **early-career skills**

- Requirements of apprenticeship training are codified in **state-approved apprenticeship plans**
- Plans are standardized across Germany by the *Vocational Training Act*
- **Nationwide standardization** and **uniform examination formalities** ensure that apprentices gain the skills stated in an apprenticeship plan

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► In total, we have classified $\approx$ **13,500 skills** from apprenticeship plans

German education system   Apprenticeship plan data

Example for Apprenticeship Plan

Apprenticeship plan for vocational training to become an e-commerce merchant

Section A: Skills, knowledge, and abilities for this professional profile

| Seq. Nr	Part of the apprenticeship profile	Skills, knowledge, and abilities to be taught	Temporal references in weeks in	
			Month 1 to 15	Month 16 to 36
1	2	3	4	
1	Selection and usage of online sales channels (§ 4 paragraph 2 number 1)	a) Select and differentiate online sales channels according to scope of services, performance, areas of application, and economic efficiency b) Evaluate user behavior and derive suggestions for improvement for online sales c) Analyze process flows and further develop concept for user-friendly interface d) Adhere to legal regulations and operational requirements, in particular regarding information obligations, competition law, trademark protection, copyright and data protection, when using the online sales channel e) Assess the technical and organizational requirements and framework conditions for the use of new online sales channels in connection with different business models and derive measures f) Cooperate with internal and external service providers in the further development and optimization of online sales systems, define scope of services and control service delivery	16	

Skill Classification (following Deming and Kahn, 2018)

Skill Groups	Keywords and Phrases
Cognitive	Math and statistics, critical/analytical thinking, problem solving and decision making, language, creativity, innovation, economics, accounting, business analysis, evaluation
Social	Teamwork, communication, negotiation, presentation, consultation and advice, customer service, service orientation, time management, adaptability, flexibility, stress tolerance
Digital	Basic computer skills, office software, data analysis, data security, software
Manual	Construction, transportation, general physical activities, maintenance, installation, repairing, tools
Management	Management of personnel and financial resources, project management
Administrative	Writing, scheduling, support activities, law and regulations

Descriptive statistics   Examples and validation

Occupational Landscape I: Cognitive and Social Skills
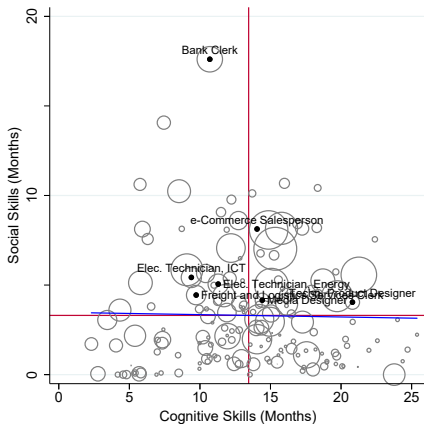
Notes: Figure plots cognitive and social skills (measured in months of learning a specific skill) in the 165 largest German apprenticeship occupations. The size of the hollow circles around the filled dots is proportional to the number of new apprentices in an occupation in 2017. Regression line shown in blue. Averages of cognitive and social skills (weighted by the number of new apprentices in 2017) are shown as red lines.
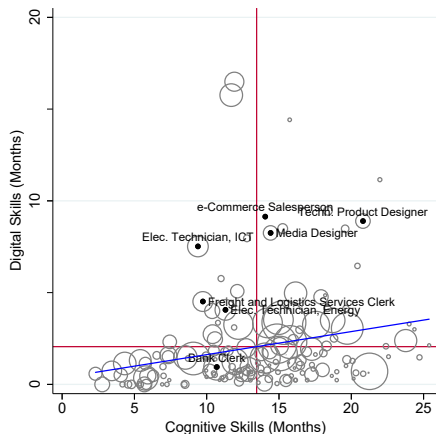
Occupational Landscape II: Cognitive and Digital Skills

Notes: Figure plots cognitive and digital skills (measured in months of learning a specific skill) in the 165 largest German apprenticeship occupations. The size of the hollow circles around the filled dots is proportional to the number of new apprentices in an occupation in 2017. Regression line shown in blue. Averages of cognitive and digital skills (weighted by the number of new apprentices in 2017) are shown as red lines.

Labour-Market Data and Empirical Strategy

► **Sample of Integrated Labour Market Biographies** (SIAB)

- Administrative data covering **2 percent** of the workforce in Germany subject to social security
- **Our sample:** Full-time workers whom we can follow more than 15 years after labour-market entry
- Skill data are **linked** to labour-market data using detailed information on the apprenticeship occupation (five-digit) in the SIAB

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► **Empirical Specification**

1. Control for **demographic characteristics:** gender, nationality, age fixed effects, and pre-apprenticeship education
2. Control for **apprenticeship characteristics:** apprenticeship field, county of training establishment, and year of apprenticeship completion
3. Leverage **complementary survey data** and **establishment information** to control even more rigorously for **selection** into apprenticeships

Regression equation

High returns to apprenticeship skills over workers' careers
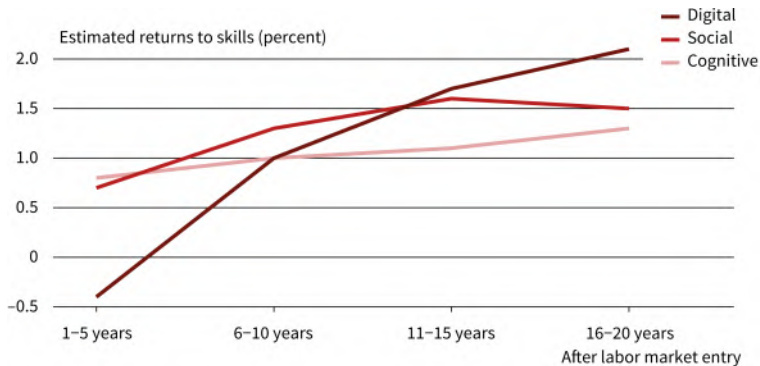
Notes: Figure shows the percentage increase in earnings for an increase in cognitive, social, and digital skills by one month over the first 20 years after labor market entry. The sample consists of full-time employees with completed apprenticeship education. The estimates account for the other skill groups (manual, management, administrative), demographic factors (gender, nationality, age fixed effects, and pre-apprenticeship educational degree), and apprenticeship characteristics (year of completion, county of training establishment, and occupational field (1-digit)).

Regression table   Returns to all skills   Wage trajectories   Skill complementarity   Skill-technology complementarity

Steep increase in returns to digital skills over last 30 years

Estimated returns to skills (percent)

Legend: Digital — Social — Cognitive

Notes: Figure shows the percentage increase in earnings for a one-month increase in cognitive, social, and digital skills for each year from 1990 to 2017. The sample consists of full-time workers with a completed apprenticeship training aged 35–54 years in a given year. Estimated returns are conditional on the other skill domains (manual, management, admin), worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree), and apprenticeship characteristics (year of completion, county of training establishment, and occupational field (1-digit)).
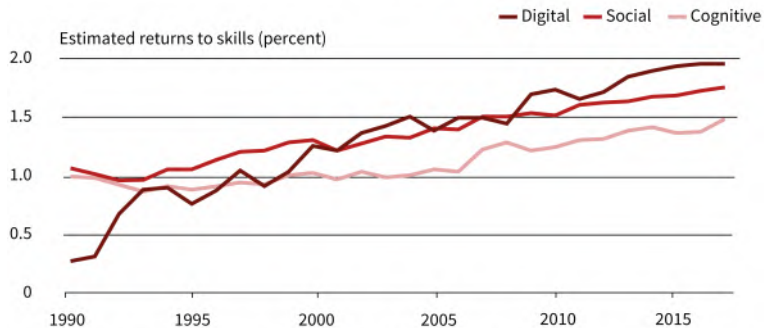
By cohort

Conclusion

▶ We derive a **detailed and comprehensive classification** of workers' early-career skills based on apprenticeship curricula in Germany

▶ Apprenticeships providing **higher cognitive or social skills** are associated with significantly **higher wages** in the short and longer run

  – Generalizes evidence that cognitive and social skills of high-wage workers are valued on the labour market (Deming and Kahn, 2018) to **low- and middle-wage workers**

▶ Higher digital skills are **not systematically related** to higher wages early in the career, but to **faster wage growth** over long-run horizons

▶ **Increasing trend in the labour-market returns** to cognitive, social, and particularly digital skills over the last three decades

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Robustness and Mechanisms

▶ **Selection into apprenticeship occupations**
  – We always estimate returns to skills **within broad apprenticeship fields**
  – In the PIAAC analysis, we account for additional **potential confounds** (e.g., school grades, family background, non-cognitive skills) PIAAC wages
  – Results robust to including establishment controls or establishment FE Establishment characteristics Establishment FE

▶ **Heterogeneity analyses**
  – Returns are qualitatively similar in **small and big firms** Small vs. big firms
  – **Gender differences:** Women have higher returns to cognitive and social skills than men, but lower returns to digital skills Gender heterogeneity

▶ **Mechanisms**
  – Human capital investments University education On-the-job training
  – Occupational switching Occupational switching

Preview of Results:
Apprenticeship Skills are Highly Valued on the Labour Market

- ► Cognitive and social skills supplied through apprenticeship training are **highly valued** in the **short and longer run**

- ► Workers with socially- or digitally-intense apprenticeships experience particularly **fast wage growth**

- ► 20 years after apprenticeship completion, one additional **month** of learning skills is related to the following wage returns:
  - **Cognitive** skills: 1.3 percent
  - **Social** skills: 1.5 percent
  - **Digital** skills: 2.1 percent
  - (Returns to one additional **year of schooling**: 7.9 percent)

- ► **Potential channels**: Educational upgrading, on-the-job training, and (avoiding) occupational switching

- ► We also document **trends in the returns** to cognitive, social, and digital skills **between 1990–2017**

Data Overview: Apprenticeship Plans

▶ Contain the **skills apprentices are required to learn** in their apprenticeship

▶ Our data cover skills from the 165 largest apprenticeship occupations (**>85 percent of the German workforce with an apprenticeship**)

▶ Each plan:
  – Corresponds to one occupation
  – States the occupational skill content with a **detailed depiction of skills** provided at every stage of the apprenticeship ($\varnothing$ 120 skills)
  – Provides the **exact number of weeks** a specific skill has to be learnt

▶ In total, we have classified $\approx$ **13,500 skills**

Examples for Skill Labels in Apprenticeship Plans

Skill Groups	Phrases in Apprenticeship Plans
Cognitive	Assessing and evaluating
	Examining and certifying
	Use technical terms in foreign languages
	Determine and define work steps
	Implementation of quality assurance measures
Social	Solve conflicts in a team
	Conduct customer conversations appropriate to the situation
	Plan and work on tasks in a team
	Presentation of results
	Contribute to the prevention of communication difficulties
Digital	Record and evaluate data relevant to the business
	Integrating IT systems into networks
	Install and configure operating systems and application programs
	Distinguish network architectures
	Use tools and test programs

Descriptive Statistics

Variable	Mean	SD	Min	Max
Apprenticeship plan characteristics				
Length (in months)	36.44	4.62	24	48
Number of detailed skills	120.02	38.45	51	248
Last update	2006	7.01	1979	2019
Skill content (months)				
Cognitive	13.45	5.00	2.31	25.38
Social	3.31	3.05	0.00	17.60
Digital	2.06	2.82	0.00	16.50
Manual	12.98	8.45	0.00	32.60
Management	0.15	0.40	0.00	3.41
Admin	4.61	3.39	0.46	23.88

Notes: Statistics are based on the 165 largest apprenticeship occupations in Germany.

Top and Bottom Apprenticeships for Cognitive, Social, and Digital Skills

				Panel A: Top 3 Apprenticeships							
Cognitive Skills				Social Skills				Digital Skills			
Occupation	Cog	Dig	Soc	Occupation	Soc	Cog	Dig	Occupation	Dig	Cog	Soc
Phys. Lab. Techn.	25.38	2.13	2.23	Bank Clerk	17.61	10.70	0.95	Comp. Systems	16.49	11.91	3.46
Materials Tester	24.72	1.47	1.40	Soc. Insurance	14.07	7.44	2.32	Comp. Software	15.76	11.70	4.40
Paint Lab Techn.	24.37	3.0	0.75	Fitness Clerk	10.68	15.99	2.44	Geom. Engineer	14.42	15.74	1.38

				Panel B: Bottom 3 Apprenticeships							
Cognitive Skills				Social Skills				Digital Skills			
Occupation	Cog	Dig	Soc	Occupation	Soc	Cog	Dig	Occupation	Dig	Cog	Soc
Painter	3.43	0.74	3.05	Interior Constr.	0.00	4.18	0.00	Build. Constr.	0.00	4.56	0.00
Carpenter	2.78	0.00	0.05	Chem. Worker	0.00	6.92	0.00	Track Layer	0.00	7.25	0.09
Baker	2.31	0.58	1.71	Civil Engineer	0.00	4.80	0.00	Carpenter	0.00	2.78	0.05

Notes: Table shows the ranking of the top and bottom three apprenticeships according to their cognitive, social, and digital skill content (in months) for the 165 largest apprenticeship occupations in Germany. For instance, an apprentice who has completed a Computer Scientist - System Integration (Comp. Systems) apprenticeship has learned digital skills for 16.49 months, cognitive skills for 11.91 months, and social skills for 3.46 months.

Examples and Validation

Apprenticeship examples:

- ▶ **Cognitive:** Physical Labouratory Technician, Tax Assistant, Technical Product Designer
- ▶ **Social:** Bank Clerk, Hotel Industry Clerk, Hairdresser
- ▶ **Digital:** IT Specialist, Geomatics Engineer, IT Management Assistant

Validation:

- ▶ Skill correlations Correlations
- ▶ Strong correlation with existing **occupation-level task measures** for Germany (Dengler and Matthes, 2018) DM
- ▶ Strong correlation with **PIAAC test scores** PIAAC scores and **PIAAC task use** PIAAC tasks
- ▶ Strong correlation between **skills over the career** Transferability over the life cycle

Apprenticeship Skill Correlations

Skill Domain	(1)	(2)	(3)	(4)	(5)	(6)
(1) Cognitive	1.000					
(2) Social	−0.021	1.000				
(3) Digital	0.222	0.149	1.000			
(4) Manual	−0.488	−0.551	−0.490	1.000		
(5) Management	−0.018	0.288	0.235	−0.290	1.000	
(6) Admin	0.036	0.446	0.117	−0.588	0.199	1.000

Notes: Skill correlations based on the 165 largest apprenticeship occupations in Germany. Occupation-level correlations are shown.

Transferability of Skills over the Life Cycle

Skill Category	1–5 years	6–10 years	11–15 years	16–20 years
A. All workers				
(1) Cognitive	0.790	0.667	0.610	0.563
(2) Social	0.874	0.808	0.778	0.750
(3) Digital	0.817	0.676	0.611	0.552
B. Occupational Switchers				
(4) Cognitive	0.620	0.465	0.388	0.369
(5) Social	0.689	0.567	0.515	0.500
(6) Digital	0.653	0.484	0.410	0.392

Notes: Correlations are based on administrative worker data at the individual level. Correlations are calculated based on the mean skill in the 5-year period indicated in the column header. We define an occupational switch as a transition to an occupation different from the apprenticeship occupation (5-digit level).
Data source: SIAB.

Validation Exercise: Dengler and Matthes (2018) Task Measures

Skill Category	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Cognitive	1.000								
(2) Social	0.072	1.000							
(3) Digital	0.324	0.186	1.000						
(4) Manual	−0.565	−0.613	−0.535	1.000					
(5) Analyt. Non-Routine	0.263	0.229	0.373	−0.472	1.000				
(6) Interact. Non-Routine	0.107	0.716	0.049	−0.545	0.151	1.000			
(7) Cognitive Routine	0.472	0.290	0.655	−0.522	0.262	0.061	1.000		
(8) Manual Routine	0.125	−0.474	−0.279	0.313	−0.499	−0.437	−0.335	1.000	
(9) Manual Non-Routine	−0.685	−0.230	−0.453	0.633	−0.414	−0.193	−0.575	−0.226	1.000

Notes: Validation exercise with task measures derived by Dengler and Matthes (2018), which approximate the automation probability of occupations based on the BERUFENET data. Correlations are based on individual-level data from our main estimation sample of full-time workers. *Data source:* SIAB.

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Empirical Specification

$$Y_{ijrty} = \alpha + \textbf{Skills}_{\textbf{j}}'\beta_1 + \textbf{Worker}_{\textbf{iy}}'\beta_2 + \textbf{Apprenticeship}_{\textbf{jrt}}'\beta_3 + \varepsilon_{ijrty}$$

Y_{ijrty}:	Outcome of individual *i* who completed an apprenticeship in occupation *j*, region *r*, and year *t* measured *y* $\in$ {1–5, 6–10, 11–15, 16–20} years afterwards
$Skills_j$:	Skills developed by completing an apprenticeship in occupation *j*
$Worker_{iy}$:	Vector of basic worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship education)
$Apprenticeship_{jrt}$:	Fixed effects for apprenticeship occupation (1-digit), county of training establishment, and year of apprenticeship completion
ε_{ijrty}:	Error term

Apprenticeship Skills and Wage Levels

	Log daily wages after			
	1−5 years (1)	6−10 years (2)	11−15 years (3)	16−20 years (4)
Cognitive skills (months)	0.008 (0.0050)	0.010** (0.0045)	0.011** (0.0044)	0.013*** (0.0042)
Social skills (months)	0.007 (0.0055)	0.013** (0.0053)	0.016*** (0.0051)	0.015*** (0.0049)
Digital skills (months)	−0.004 (0.0056)	0.010 (0.0065)	0.017** (0.0077)	0.021*** (0.0080)
All skills	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship controls				
Completion year FE	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes
F-statistic (all skills)	1.7	4.9	7.0	8.1
N (individuals)	66,432	66,432	66,432	66,432

Notes: Sample consists of workers with a completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labour-market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Column 1 corresponds to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill during the apprenticeship. We control for the other skill groups (manual, management, admin) and worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data source:* SIAB.

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All Skill Coefficients

	Log daily wages after			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Cognitive skills (months)	0.008	0.010**	0.011**	0.013***
	(0.0050)	(0.0045)	(0.0044)	(0.0042)
Social skills (months)	0.007	0.013**	0.016***	0.015***
	(0.0055)	(0.0053)	(0.0051)	(0.0049)
Digital skills (months)	−0.004	0.010	0.017**	0.021***
	(0.0056)	(0.0065)	(0.0077)	(0.0080)
Admin skills (months)	0.003	−0.001	−0.001	0.000
	(0.0045)	(0.0049)	(0.0059)	(0.0064)
Management skills (months)	0.030	0.030	0.038	0.032
	(0.0224)	(0.0232)	(0.0238)	(0.0246)
Manual skills (months)	−0.002	−0.002	−0.002	0.000
	(0.0029)	(0.0028)	(0.0032)	(0.0033)
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship controls				
Completion year FE	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes
F-statistic (all skills)	1.7	4.9	7.0	8.1
N (individuals)	66,432	66,432	66,432	66,432

Notes: Sample consists of male workers with a completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labour-market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Column 1 corresponds to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill during the apprenticeship. worker characteristics are nationality, age fixed effects, and pre-apprenticeship educational degree. Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data source*: SIAB.

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Unrestricted Sample

	Log daily wages after			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Cognitive skills (months)	0.016*** (0.0053)	0.016*** (0.0049)	0.015*** (0.0046)	0.015*** (0.0044)
Social skills (months)	0.014** (0.0061)	0.017*** (0.0054)	0.019*** (0.0054)	0.017*** (0.0051)
Digital skills (months)	−0.003 (0.0061)	0.007 (0.0071)	0.016** (0.0078)	0.024*** (0.0082)
All skills	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship controls				
Completion year FE	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes
F-statistic (all skills)	4.0	6.6	8.5	10.6
N (individuals)	204,007	155,816	111,609	78,898

Notes: Sample consists of workers with a completed apprenticeship training who have at least one full-time employment spell in the period indicated in the column header. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Column 1 corresponds to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill during the apprenticeship. worker characteristics are nationality, age fixed effects, and pre-apprenticeship educational degree. Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. *Data source:* SIAB.

Apprenticeship Skills and Wage Trajectories

	Wage growth relative to initial period ($\times$ 100)		
	6–10 years (1)	11–15 years (2)	16–20 years (3)
Cognitive skills (months)	0.026 (0.0214)	0.025 (0.0192)	0.029* (0.0163)
Social skills (months)	0.104*** (0.0172)	0.085*** (0.0154)	0.054*** (0.0136)
Digital skills (months)	0.243*** (0.0333)	0.193*** (0.0316)	0.160*** (0.0261)
All skills	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes
Apprenticeship controls			
Completion year FE	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes
Outcome mean	2.05	1.47	1.17
F-statistic (all skills)	18.57	14.05	10.29
N (individuals)	66,432	66,432	66,432

Notes: Sample consists of full-time workers with completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labour-market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is the average annual growth rate of wages (multiplied by 100) between the first five years after apprenticeship completion and the period indicated in the column header (e.g., Column 1 corresponds to the growth between the average wage in the years 1–5 after apprenticeship completion and the average wage in the years 6–10). Early-career skills are measured in months of learning the respective skill during the apprenticeship. We control for the other skill groups (manual, management, admin) and worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. *Data source:* SIAB.

Apprenticeship Skill Interactions

	Log daily wages after			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Cognitive skills (months)	0.012*** (0.0043)	0.012*** (0.0039)	0.012*** (0.0040)	0.014*** (0.0040)
Social skills (months)	0.012** (0.0056)	0.015*** (0.0055)	0.016*** (0.0057)	0.015*** (0.0055)
Digital skills (months)	−0.004 (0.0051)	0.010* (0.0057)	0.018*** (0.0064)	0.022*** (0.0069)
Skill interactions				
Cognitive skills × social skills	0.003*** (0.0008)	0.002*** (0.0009)	0.002** (0.0009)	0.002** (0.0010)
Cognitive skills × digital skills	−0.002* (0.0009)	−0.002** (0.0009)	−0.002** (0.0010)	−0.002** (0.0010)
Social skills × digital skills	−0.004 (0.0028)	−0.003 (0.0030)	−0.003 (0.0033)	−0.004 (0.0033)
All skills	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship controls				
Completion year FE	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes
N (individuals)	66,432	66,432	66,432	66,432

Notes: Sample consists of workers with completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labour-market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Column 1 corresponds to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months; all skill measures are de-meaned. We control for the other skill groups (manual, management, admin) and worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data source:* SIAB.

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Returns to Skills and Firms' Skill Demand

	Log daily wage					
	(1)	(2)	(3)	(4)	(5)	(6)
Cognitive skills (months)	0.016***	0.016***	0.016***			
	(0.0041)	(0.0041)	(0.0041)			
× Cognitive skill demand	0.002***			0.001***		
	(0.0006)			(0.0005)		
× Social skill demand		−0.000			−0.000	
		(0.0004)			(0.0003)	
× Digital skill demand			0.001**			0.001*
			(0.0006)			(0.0005)
All skills	Yes	Yes	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Apprenticeship controls						
Completion year FE	Yes	Yes	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	No	No	No
Occupation FE (5-digit)	No	No	No	Yes	Yes	Yes
N (individuals × years)	721,508	721,508	721,508	721,508	721,508	721,508

Notes: Sample consists of full-time workers with a completed apprenticeship training. We only include data for the years 2014 to 2017 to ensure a direct overlap of our apprenticeship skill data with OJV data. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is log daily wages. Early-career skills are measured in months and are de-meaned to facilitate interpretation. Skill demand is measured as the share of job ads in the county of a worker's current establishment that requests a specific skill, standardized with mean zero and standard deviation one. We control for the other skill groups (manual, management, admin) and worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data sources:* SIAB and Lightcast.

Gender Heterogeneity

	Log daily wages after			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Panel A: Males				
Cognitive skills (months)	0.005 (0.0047)	0.007 (0.0044)	0.009* (0.0043)	0.010** (0.0042)
Social skills (months)	0.003 (0.0051)	0.009* (0.0049)	0.013** (0.0050)	0.014*** (0.0048)
Digital skills (months)	−0.004 (0.0055)	0.012* (0.0060)	0.019*** (0.0070)	0.024*** (0.0069)
F-statistic (all skills)	0.7	3.6	6.3	7.7
N (individuals)	47,827	47,827	47,827	47,827
Panel B: Females				
Cognitive skills (months)	0.015** (0.0060)	0.014** (0.0063)	0.012* (0.0072)	0.013* (0.0067)
Social skills (months)	0.016*** (0.0058)	0.018*** (0.0062)	0.018** (0.0071)	0.014** (0.0067)
Digital skills (months)	0.006 (0.0107)	0.007 (0.0102)	0.008 (0.0114)	0.013 (0.0113)
F-statistic (all skills)	7.6	9.9	12.6	12.1
N (individuals)	18,605	18,605	18,605	18,605
Further controls	Yes	Yes	Yes	Yes

Notes: Sample consists of male workers (Panel A) and female workers (Panel B) with a completed apprenticeship training. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Column 1 corresponds to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill during the apprenticeship. All models control for the other skill groups (manual, management, admin), worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree), and apprenticeship controls (year of completion, county of training establishment, and occupational field (1-digit)). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p $<$ 0.01, ** p $<$ 0.05, * p $<$ 0.1. *Data source:* SIAB.

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Heterogeneity by Firm Size

	Log daily wages after			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Panel A: Small Apprenticeship Establishments				
Cognitive skills (months)	0.009 (0.0060)	0.012** (0.0054)	0.015*** (0.0048)	0.016*** (0.0044)
Social skills (months)	0.003 (0.0103)	0.012 (0.0103)	0.017* (0.0092)	0.016* (0.0081)
Digital skills (months)	−0.005 (0.0065)	0.010 (0.0070)	0.019** (0.0073)	0.026*** (0.0074)
F-statistic (all skills)	1.7	6.4	10.0	13.0
N (individuals)	29,374	29,374	29,374	29,374
Panel B: Large Apprenticeship Establishments				
Cognitive skills (months)	0.006 (0.0038)	0.006 (0.0036)	0.006 (0.0038)	0.009** (0.0038)
Social skills (months)	0.009** (0.0034)	0.013*** (0.0033)	0.015*** (0.0036)	0.015*** (0.0036)
Digital skills (months)	0.002 (0.0048)	0.015** (0.0058)	0.022*** (0.0074)	0.025*** (0.0080)
F-statistic (all skills)	1.6	4.9	6.2	6.1
N (individuals)	37,058	37,058	37,058	37,058
Further controls	Yes	Yes	Yes	Yes

Notes: Regression results are shown separately for workers who finished their apprenticeship in a "small" establishment (1-37 employees) in Panel A vs. a "large" establishment (38-16,870 employees) in Panel B. Size categories are based on a median split in the number of full-time employees at apprenticeship completion. Sample consists of full-time workers with a completed apprenticeship training. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is log daily wages by years after apprenticeship completion (e.g., Column 1 corresponds to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill during the apprenticeship. All models control for the other skill groups (manual, management, admin), worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree), and apprenticeship controls (year of completion, county of training establishment, and occupational field (1-digit)). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data source:* SIAB.

Robustness: Accounting for Potential Confounds

Table: Apprenticeship Skills and Wages (PIAAC)

	Log hourly wages			
	(1)	(2)	(3)	(4)
Cognitive skills (months)	0.021*** (0.006)	0.019*** (0.006)	0.020*** (0.007)	0.020*** (0.007)
Social skills (months)	0.029*** (0.007)	0.028*** (0.007)	0.027*** (0.008)	0.026*** (0.008)
Digital skills (months)	0.014 (0.009)	0.013 (0.009)	0.018* (0.010)	0.017* (0.010)
All skills	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship occupation FE (1-digit)	Yes	Yes	Yes	Yes
High-school grades	No	Yes	Yes	Yes
Family background	No	No	Yes	Yes
Non-cognitive skills	No	No	No	Yes
F-statistic (all skills)	7.2	6.5	6.6	7.0
N (individuals)	613	613	613	613

Notes: Sample consists of full-time workers aged 35-65 years with a completed apprenticeship training. Dependent variable is log hourly wages. Early-career skills are measured in months of learning the respective skill during the apprenticeship. All specifications control for the other skill domains (manual, management, admin), worker characteristics (gender, migrant status, quadratic polynomial in age, and highest pre-apprenticeship educational degree (8 categories)), and 1-digit apprenticeship occupation fixed effects. High-school grades are final grades in math, German, and foreign language upon completing secondary education. Family background comprises the highest level of education obtained by the respondent's mother/father in three categories (no vocational or university education, vocational, university) and the occupation of the mother/father when the respondent was 15 years old (2-digit level). Non-cognitive skills include the Big 5 personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism) and grit. Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p $<$ 0.01, ** p $<$ 0.05, * p $<$ 0.1. *Data source:* PIAAC.

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Robustness: Early-Career Skills and Test Scores (PIAAC)

	PIAAC Test Scores		
	Numeracy (1)	Literacy (2)	ICT (3)
Cognitive skills (months)	0.018*** (0.007)	0.014* (0.008)	0.008 (0.008)
Social skills (months)	0.021*** (0.007)	0.015* (0.008)	0.001 (0.009)
Digital skills (months)	0.032*** (0.009)	0.030** (0.012)	0.031*** (0.012)
All skills	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes
F-statistic (all skills)	17.1	10.6	12.3
N (individuals)	1,612	1,612	1,365

Notes: Sample consists of PIAAC respondents with a completed apprenticeship training. Dependent variables are test scores in numeracy (Column 1), literacy (Column 2), problem-solving in technology-rich environments, which we refer to as ICT skills (Column 3). The smaller number of observations in Column 3 is due to the fact that ICT skills could not be tested for respondents who did not participate in PIAAC in a computer-based mode. There are three reasons for why respondents did not participate in a a computer-based mode [see][]Falck2020: (i) individuals had no prior computer experience; (ii) individuals failed a computer core test, which assessed basic digital competencies such as using a keyboard/mouse or scrolling through a web page; (iii) individuals refused to take part in the computer-based assessment. All test scores are standardized with standard deviation 1 in the entire PIAAC sample. Early-career skills are measured in months of learning the respective skill during the apprenticeship. All specifications control for the other skill domains (manual, management, admin) and worker characteristics (gender, migrant status, quadratic polynomial in age, and highest pre-apprenticeship educational degree (8 categories)). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p $<$ 0.01, ** p $<$ 0.05, * p $<$ 0.1. Data source: PIAAC.

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Robustness: Early-Career Skills and Job Tasks (PIAAC)

	Task Content					
	Numeracy (Simple) (1)	Numeracy (Advanced) (2)	Social (3)	Experience w/ Computer (4)	Computer Use (5)	Internet Use (6)
Cognitive skills (months)	0.014 (0.011)	0.005 (0.009)	−0.001 (0.013)	0.008 (0.006)	0.001 (0.019)	−0.006 (0.017)
Social skills (months)	0.006 (0.015)	0.002 (0.014)	0.026* (0.014)	0.009 (0.007)	−0.000 (0.019)	−0.012 (0.023)
Digital skills (months)	−0.005 (0.013)	0.023* (0.012)	−0.009 (0.014)	0.023*** (0.007)	0.061*** (0.020)	−0.003 (0.013)
All skills	Yes	Yes	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic (all skills)	4.3	3.4	8.2	10.6	4.6	4.9
N (individuals)	1,414	1,413	1,411	1,414	1,025	1,026

Notes: Sample consists of PIAAC respondents with a completed apprenticeship training. Dependent variables measure the task content of a worker's current job in several dimensions: Simple numeracy tasks (Column 1), advanced numeracy tasks (Column 2), social tasks (Column 3), experience with computers (Column 4), computer use (Column 5), and internet use (Column 6). The smaller number of observations in Columns 5 and 6 are due to the fact that ICT task use at work questions were not asked to respondents who do not use a computer at work. The simple numeracy task index is based on questions examining how often a respondent performs the following activities at work: calculating costs or budgets, use or calculate fractions or percentages, use a calculator, and prepare charts, graphs, or tables. The advanced numeracy tasks index is based on questions asking how often respondents use algebra or formulas and advanced math or statistics at the job. To construct the social tasks index, we use questions asking how often respondents perform the following activities at the job: advising people, influencing people, negotiating with people, selling. The experience with computer indicator is based on a question asking whether respondents have experience with computers in their job. The computer use index is based on questions asking respondents how often they perform the following activities at work: use spreadsheets, word, programming language, and real-time discussions. The internet use index is based on questions on how often a respondent uses the internet for the following purposes: mail, acquiring work-related information, and conducting transactions. Answer categories (with the exception of the computer experience indicator) are on a 5-point scale that ranges from never to every day. Following the procedure by [?], we construct the task indices as an equally weighted average of the z-scores of the included items. The resulting index is again standardized with standard deviation 1 in the entire PIAAC sample. Early-career skills are measured in months of learning the respective skill during the apprenticeship. All specifications control for the other skill domains (manual, management, admin) and worker characteristics (gender, migrant status, quadratic polynomial in age, and highest pre-apprenticeship educational degree (8 categories)). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data source:* PIAAC.

Robustness: Controlling for Establishment Characteristics

	Log daily wages after							
	1–5 yrs (1)	1–5 yrs (2)	6–10 yrs (3)	6–10 yrs (4)	11–15 yrs (5)	11–15 yrs (6)	16–20 yrs (7)	16–20 yrs (8)
Cognitive skills (months)	0.009*	0.003*	0.012**	0.005***	0.013***	0.006***	0.014***	0.008***
	(0.0052)	(0.0018)	(0.0047)	(0.0018)	(0.0045)	(0.0020)	(0.0045)	(0.0025)
Social skills (months)	0.008	0.003	0.014***	0.008**	0.018***	0.010**	0.018***	0.009**
	(0.0055)	(0.0029)	(0.0051)	(0.0036)	(0.0051)	(0.0040)	(0.0049)	(0.0044)
Digital skills (months)	−0.007	0.001	0.008	0.015***	0.015**	0.022***	0.021***	0.028***
	(0.0057)	(0.0035)	(0.0064)	(0.0040)	(0.0073)	(0.0047)	(0.0076)	(0.0057)
All skills	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Apprenticeship controls								
Completion year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of full-time employees	No	Yes	No	Yes	No	Yes	No	Yes
Establishment age	No	Yes	No	Yes	No	Yes	No	Yes
Establishment industry (3-digit)	No	Yes	No	Yes	No	Yes	No	Yes
AKM Effects	No	Yes	No	Yes	No	Yes	No	Yes
F-statistic (all skills)	2.3	4.9	5.2	7.4	7.7	10.9	8.6	8.4
N (individuals)	51,612	51,612	51,612	51,612	51,612	51,612	51,612	51,612

Notes: Sample consists of workers with a completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labor market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Columns 1 and 2 correspond to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill groups (manual, management, admin) and worker characteristics (nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls include year of completion, county of training establishment, and occupational field (1-digit). In the even columns, we add the following additional apprenticeship establishment controls: Number of full-time employees, age, industry (3-digit), and productivity (measured by AKM effects). All establishment controls are measured at the year of completing the apprenticeship. Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. *Data source:* SIAB.

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Robustness: Controlling for Establishment Fixed Effects

	Log daily wages after							
	1–5 yrs (1)	1–5 yrs (2)	6–10 yrs (3)	6–10 yrs (4)	11–15 yrs (5)	11–15 yrs (6)	16–20 yrs (7)	16–20 yrs (8)
Cognitive skills (months)	0.004	0.002	0.005	0.005**	0.006	0.005**	0.008**	0.007**
	(0.0037)	(0.0021)	(0.0036)	(0.0022)	(0.0039)	(0.0024)	(0.0037)	(0.0029)
Social skills (months)	0.007**	0.003	0.010***	0.004	0.011***	0.006	0.011***	0.005
	(0.0033)	(0.0041)	(0.0034)	(0.0038)	(0.0038)	(0.0041)	(0.0038)	(0.0055)
Digital skills (months)	0.001	0.004	0.014**	0.012***	0.020***	0.015***	0.022***	0.018***
	(0.0039)	(0.0031)	(0.0058)	(0.0043)	(0.0069)	(0.0048)	(0.0073)	(0.0051)
All skills	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Apprenticeship controls								
Completion year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County of establishment FE	Yes	No	Yes	No	Yes	No	Yes	No
Occupation FE (1-digit)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Establishment FE	No	Yes	No	Yes	No	Yes	No	Yes
F-statistic (all skills)	1.3	8.2	3.3	5.8	5.3	5.1	6.4	5.8
N (individuals)	23,893	23,893	23,893	23,893	23,893	23,893	23,893	23,893

Notes: Sample consists of workers with a completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labor market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is mean log daily wages in a 5-year period after apprenticeship completion (e.g., Columns 1 and 2 correspond to the mean log daily wages in years 1 to 5 after apprenticeship completion). Early-career skills are measured in months of learning the respective skill during the apprenticeship. We control for the other skill groups (manual, management, admin) and worker characteristics (nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, occupational field (1-digit). In the even columns, we control for apprenticeship establishment fixed effects. Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. *Data source:* SIAB.

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Mechanisms: Educational Upgrading

	University education (× 100)			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Cognitive skills (months)	−0.030 (0.0380)	0.001 (0.0629)	0.004 (0.0821)	0.013 (0.0936)
Social skills (months)	−0.038 (0.0486)	0.151** (0.0708)	0.282*** (0.0823)	0.336*** (0.1080)
Digital skills (months)	0.312*** (0.1110)	0.901*** (0.2170)	1.150*** (0.2860)	1.310*** (0.3040)
All skills	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship controls				
Completion year FE	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes
Outcome mean (in percent)	2.24	5.07	6.90	8.46
F-statistic (all skills)	5.4	6.1	6.3	6.3
N (individuals)	66,432	66,432	66,432	66,432

Notes: Sample consists of full-time workers with a completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labour-market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is a binary indicator of university education, taking a value of 1 if the worker obtains a university degree in the period indicated in the column header, and 0 otherwise. Early-career skills are measured in months of learning the respective skill during the apprenticeship. We control for the other skill groups (manual, management, admin) and worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. *Data source*: SIAB.

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Mechanisms: Early-Career Skills and Training

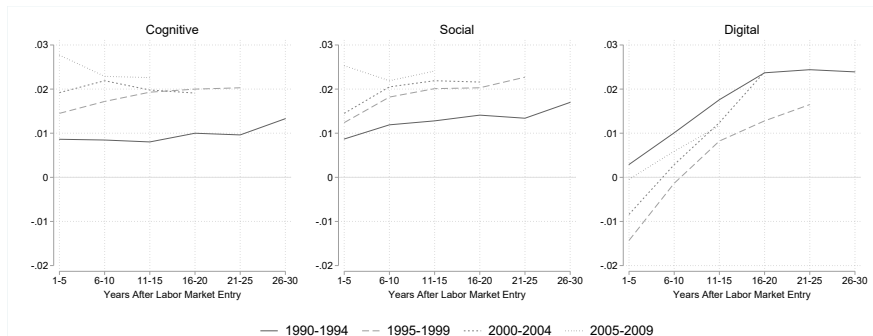|	On-the-Job Training			
	(1)	(2)	(3)	(4)
Panel A: Age 35–65				
Cognitive skills (months)	0.005	0.005	0.001	0.003
	(0.006)	(0.006)	(0.007)	(0.007)
Social skills (months)	0.009	0.006	0.004	0.005
	(0.006)	(0.006)	(0.007)	(0.007)
Digital skills (months)	0.022**	0.018**	0.020**	0.018*
	(0.009)	(0.008)	(0.010)	(0.010)
Outcome mean	0.44			
F-statistic (all skills)	2.4	2.6	1.4	1.5
N (individuals)	739	739	739	739
Panel B: Below Age 40				
Cognitive skills (months)	0.017*	0.017*	0.014	0.016*
	(0.010)	(0.009)	(0.008)	(0.009)
Social skills (months)	0.014	0.015	0.007	0.009
	(0.017)	(0.016)	(0.019)	(0.019)
Digital skills (months)	0.047***	0.047***	0.045***	0.048***
	(0.013)	(0.013)	(0.012)	(0.012)
Outcome mean	0.46			
F-statistic (all skills)	2.9	2.9	3.0	3.3
N (individuals)	418	418	418	418
Baseline controls	Yes	Yes	Yes	Yes
High-school grades	No	Yes	Yes	Yes
Family background	No	No	Yes	Yes
Non-cognitive skills	No	No	No	Yes

Notes: Sample consists of full-time workers aged 35-65 years (Panel A) or aged 16-39 years (Panel B) with a completed apprenticeship training. Dependent variable is an indicator of training on-the-job, which takes a value of 1 if the person has participated in an on-the-job training during the 12 months prior to the survey, and 0 otherwise. Early-career skills are measured in months of learning the respective skill during the apprenticeship. Baseline controls include the other skill domains (manual, management, admin), worker characteristics (gender, migrant status, quadratic polynomial in age, and highest educational degree (8 categories)), and 1-digit apprenticeship occupation fixed effects. High-school grades are final grades in math, German, and foreign language upon completing secondary education. Family background comprises the highest level of education obtained by the respondent's mother/father in three categories (no vocational or university education, vocational, university) and the occupation of the mother/father when the respondent was 15 years old (2-digit level). Non-cognitive skills include the Big 5 personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism) and grit. Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p < 0.01, ** p < 0.05, * p < 0.1. Data source: PIAAC.

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Mechanisms: Occupational Switching

	Occupational switching after			
	1–5 years (1)	6–10 years (2)	11–15 years (3)	16–20 years (4)
Cognitive skills (months)	−0.004 (0.0035)	−0.001 (0.0033)	0.000 (0.0036)	0.002 (0.0038)
Social skills (months)	−0.018*** (0.0047)	−0.014*** (0.0041)	−0.018*** (0.0046)	−0.023*** (0.0050)
Digital skills (months)	−0.011 (0.0080)	−0.001 (0.0081)	0.000 (0.0071)	0.005 (0.0055)
All skills	Yes	Yes	Yes	Yes
Worker characteristics	Yes	Yes	Yes	Yes
Apprenticeship controls				
Completion year FE	Yes	Yes	Yes	Yes
County of establishment FE	Yes	Yes	Yes	Yes
Occupation FE (1-digit)	Yes	Yes	Yes	Yes
Outcome mean	0.52	0.60	0.68	0.79
F-statistic (all skills)	2.9	2.9	3.4	6.0
N (individuals)	66,432	66,432	66,432	66,432

Notes: Sample consists of full-time workers with a completed apprenticeship training whom we can follow in the first four consecutive 5-year periods after labour-market entry. To be included in the sample, a worker needs to be observed at least once in full-time employment in each of the four consecutive 5-year periods. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. Dependent variable is a binary indicator of occupational switching, taking a value of 1 if a worker is observed at least once in an occupation different from the apprenticeship occupation (4-digit level) in the period indicated in the column header, and 0 otherwise. Early-career skills are measured in months of learning the respective skill during the apprenticeship. We control for the other skill groups (manual, management, admin) and worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree). Apprenticeship controls contain year of completion, county of training establishment, and occupational field (1-digit). Robust standard errors, shown in parentheses, are clustered at the level of the apprenticeship occupation. Significance levels: *** p < 0.01, ** p < 0.05, * p < 0.1. *Data source:* SIAB.

Returns by Cohort

Cognitive | Social | Digital

Years After Labor Market Entry

— 1990-1994   – – 1995-1999   ⋯⋯ 2000-2004   ⋯⋯⋯ 2005-2009

Notes: Sample consists of individuals with a completed apprenticeship training who work full-time in a given year. If a worker has completed more than one apprenticeship, we consider only the first apprenticeship to measure early-career skills. The dependent variable is log daily wages. Returns to skills are estimated separately for each labour-market entry cohort indicated in the graph by potential experience bin. Potential experience is defined as the number of years elapsed since a worker finished her apprenticeship. Early-career skills are measured in months of learning the respective skill during the apprenticeship. Estimated returns are conditional on the other skill domains (manual, management, admin), worker characteristics (gender, nationality, age fixed effects, and pre-apprenticeship educational degree), and apprenticeship characteristics (year of completion, county of training establishment, and occupational field (1-digit)). *Data source:* SIAB.

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Description of Job Skills

Job Skills	Keywords and Phrases
Cognitive	Problem solving, research, analytical, critical thinking, math, statistics
Social	Communication, teamwork, collaboration, negotiation, presentation
Character	Organized, detail oriented, multitasking, time management, meeting deadlines, energetic
Writing	Writing
Customer service	Customer, sales, client, patient
Project management	Project management
People management	Supervisory, leadership, management (not project), mentoring, staff
Financial	Budgeting, accounting, finance, cost
Computer (general)	Computer, spreadsheets, common software (e.g., Microsoft Excel, PowerPoint)
Software (specific)	Programming language or specialized software (e.g., Java, SQL, Python)

NOTE.—Shown is the authors categorization of open text fields in Burning Glass Technologies data.

Figure: Skill Correlations in Deming and Kahn (2018)

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Deming & Kahn, 2018: BGT Skill Correlations

Table 2
Correlations of Skill Requirements

	Education	Experience	Cognitive	Social	Character	Writing	Customer Service	Project Mgmt	People Mgmt	Financial	Computer	Software
Years of education required	1.00											
Years of experience required	.30	1.00										
Cognitive	.20	.37	1.00									
Social	.05	.25	.64	1.00								
Character	−.06	.14	.59	.69	1.00							
Customer service	−.27	−.38	−.03	.17	.14	1.00						
Writing	.12	.24	.57	.52	.52	−.07	1.00					
Project mgmt	.20	.57	.55	.45	.39	−.20	.39	1.00				
People mgmt	−.05	.01	.35	.34	.38	.13	.30	.27	1.00			
Financial	.02	.21	.43	.35	.37	−.04	.36	.38	.39	1.00		
Computer (general)	−.06	.27	.52	.52	.54	−.02	.50	.40	.24	.41	1.00	
Software (specific)	.26	.61	.36	.25	.11	−.33	.24	.50	−.06	.02	.27	1.00

NOTE.—The table shows ad-weighted bivariate correlations across all skill measures at the firm level using the firm sample. See table 1 for skills definitions. mgmt = management.

Figure: Skill Correlations in Deming and Kahn (2018)

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Process of Restructuring Apprenticeship Plans

Research project / report of the BIBB	Preliminary talks of social partners (e.g., unions, employers' associations)	Instruction of the responsible ministry

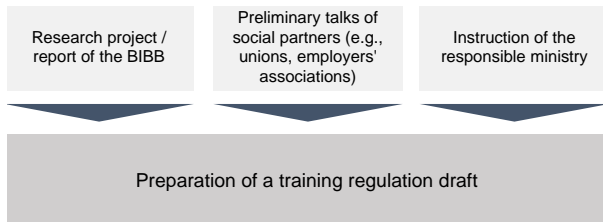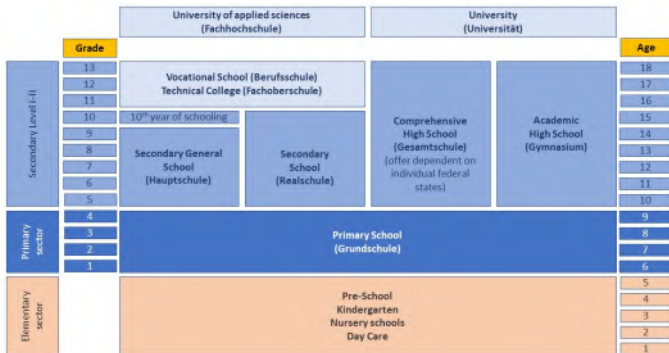**Preparation of a training regulation draft**

Figure: Initiation of restructuring process

Steps in the subsequent procedure of creating a training regulations draft:

1. Determination of the basic parameters of the training regulation
2. Preparation and consultation phase
3. Decree of the training regulations

Source: *Ausbildungsordnungen und wie sie entstehen, BIBB (2015)*

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The German Education System