Analyzing Physics and Chemistry Education in U.S. Schools with State-Level Data Sets

Korean Association for Science Education

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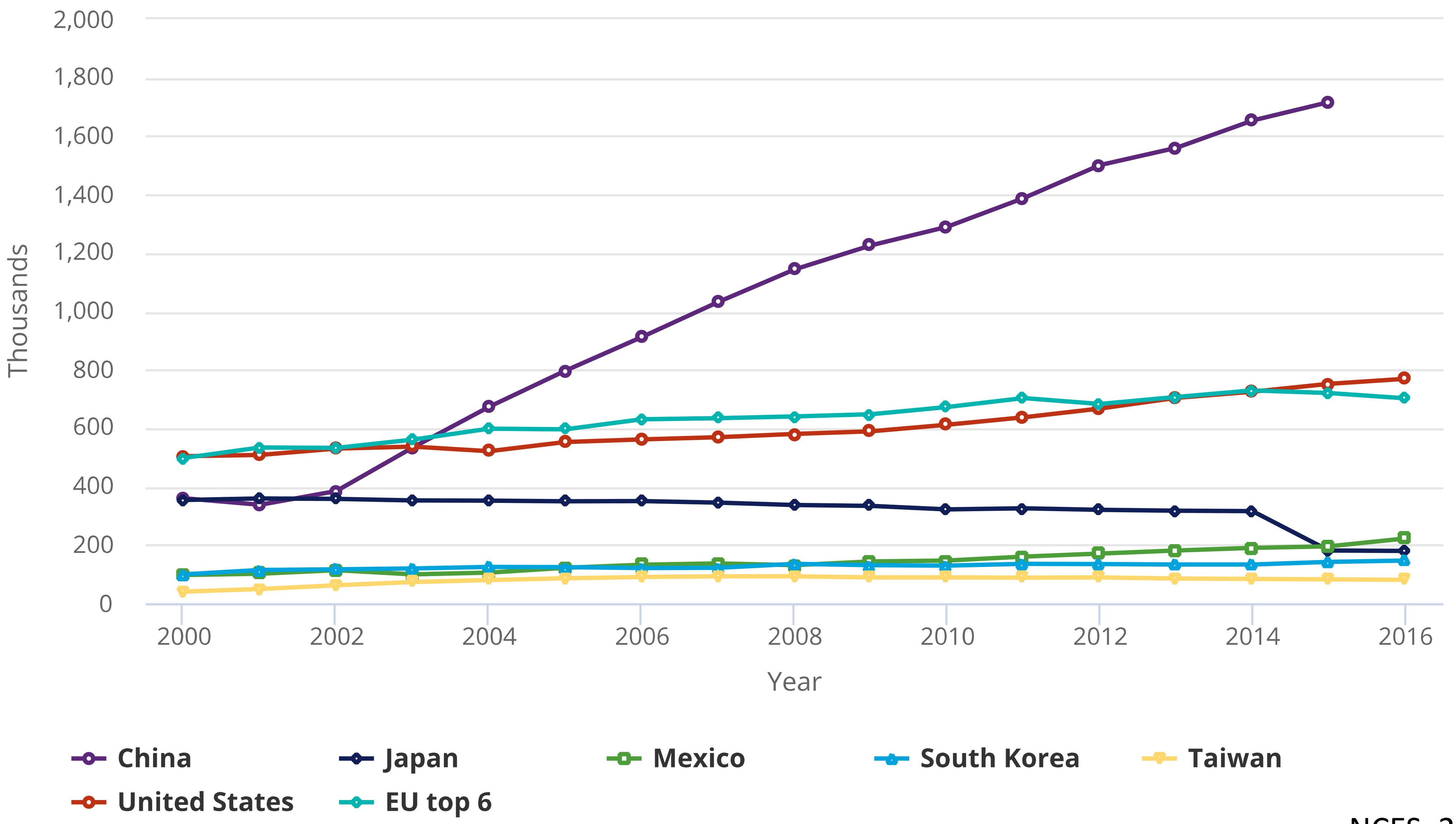
Project Rationale

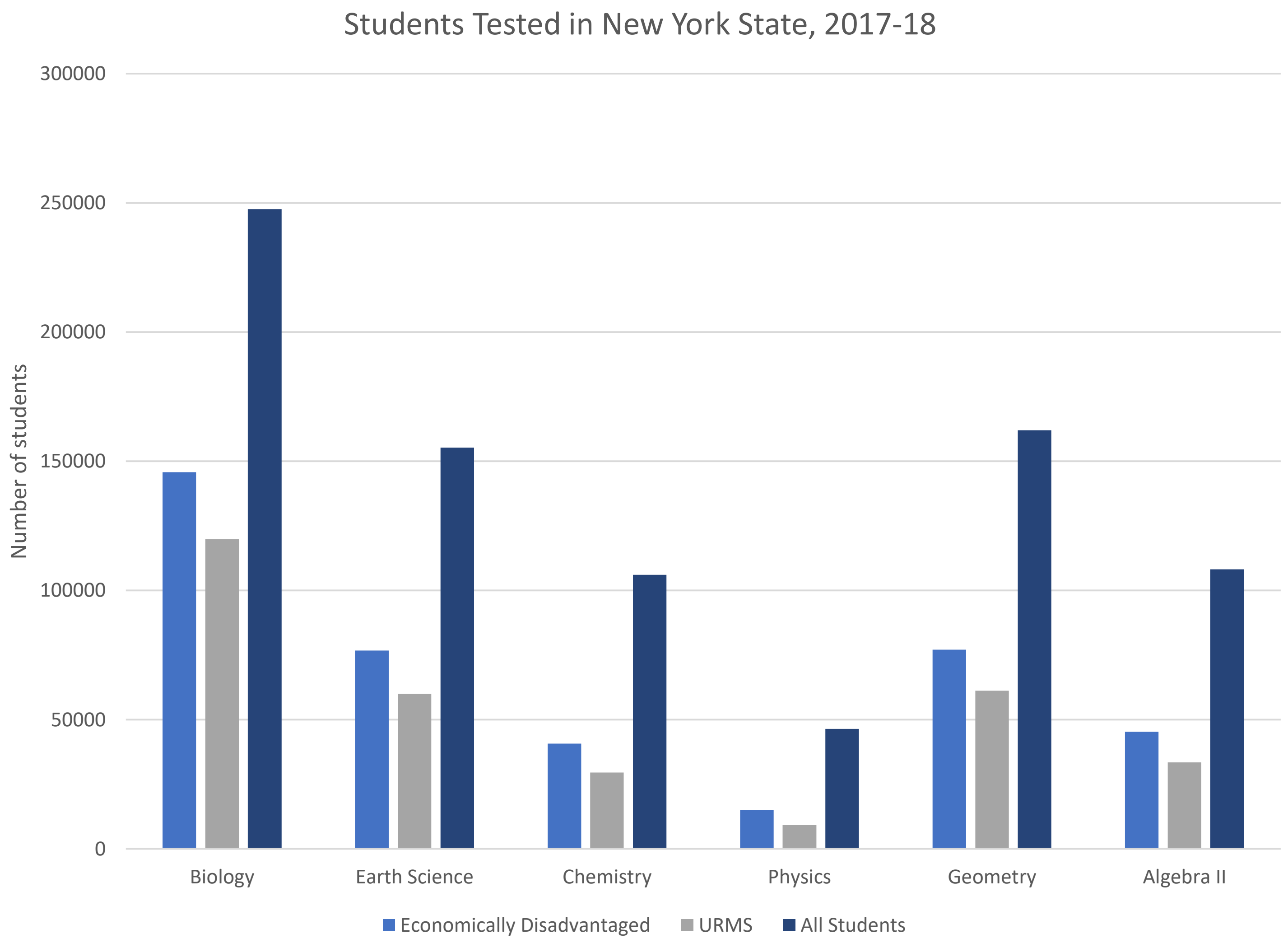
- The physical sciences (physics and chemistry) are not taken by all high school students in the U.S.
  - Approximately 39% of high school students take physics (White & Tesfaye, 2014), and 70% of students take chemistry before graduating (NCES, *Science & Engineering* Indicators, 2018).
- U.S. schools have decentralized control, with states making decisions on standards, graduation requirements, and teacher certification.
- States have published data on student performance since the passage of the *No Child Left Behind* law in 2002.
  - These robust data sets provide contextual information on student participation in the physical sciences and how teachers are certified.
  - New York State has required standardized exams in science since the late 1800s.

First university degrees in S&E, by selected region, country, or economy: 2000–16



NCES, 2018

How do physics and chemistry coursetaking compare to other sciences and mathematics?



Krakehl & Kelly. (2021, under review).

Context: Where is physics taught?

Locale	Total Number of Schools[1]	Number Schools Offering Physics (%)	Teachers of Physics (%)
Urban	516	249 (48)	367 (26)
Rural	282	257 (91)	291 (21)
Suburban	386	366 (95)	729 (53)
Total	1184	872 (74)	1387

Sheppard et al. (2020). Out-of-field teaching in chemistry and physics: An empirical census study. *Journal of Science Teacher Education, 31*(7), 746-767. https://doi.org/10.1080/1046560X.2019.1702268

What Are the Primary Certifications of Physics Teachers?

Primary Certification of Physics Teachers	Number Certified	% of All Physics Teachers
Physics	821	59
Biology	180	13
Chemistry	169	12
Earth Science	91	7
Mathematics	76	5
Non-Science/Mathematics	43	3

Sheppard et al. (2020).

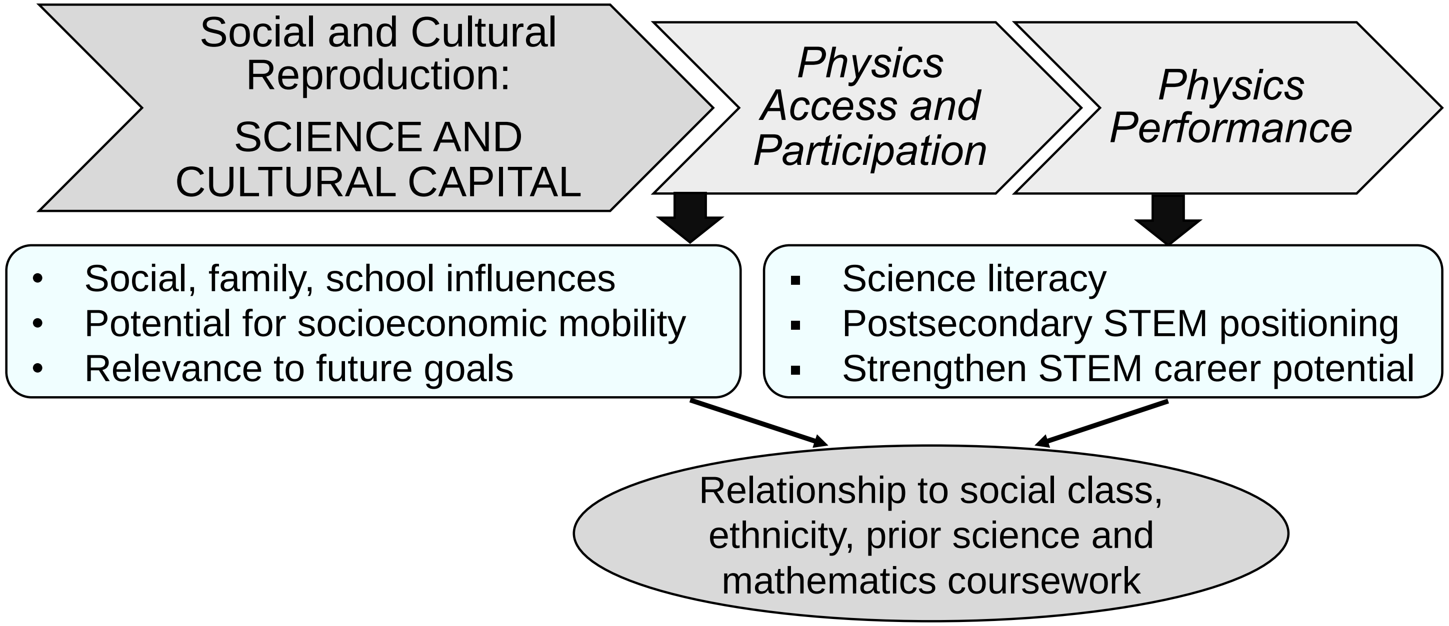
What are potential teacher and school-level variables that predict physics performance?

(F(7,439)=39.685, p<.001); adjusted R^2 = 0.378, a large effect

Variable	Standardized regression coefficient *b*	Unstandardized regression coefficient *B*	95% Confidence Interval		p-value
			Lower	Upper	
Urban school locale	–0.301	–17.705	–24.280	–11.129	<.001
Socioeconomic status (%FRL)	–0.229	–0.298	–0.434	–0.163	<.001
Rural school locale	0.151	7.565	3.268	11.863	.001
Professional age (years of teaching experience)	0.109	0.278	0.063	0.492	.011

Krakehl, Kelly, Sheppard, & Palermo. (2020). Physics teacher isolation, contextual characteristics, and student performance. *Physical Review Physics Education Research.*

Science Capital Influencing Physics Performance



Adapted from Bourdieu, 1977; Archer et al., 2018; DeWitt et al., 2016

RESEARCH QUESTIONS

1. How does student performance in precollege science and mathematics vary by ethnicity and socioeconomic status?
2. How do demographic and science and mathematics course performance variables predict physics performance?
3. How might academic variables mediate physics performance for students traditionally underrepresented in STEM?

N=1237 high schools in New York State; *N*=811,000 students in grades 9-12

Multivariable Regression Model Predicting Physics Performance

Model with accounted for 51.7% of the variance in physics performance, $F(11,651) = 65.353$, $p<0.001$, Cohen's $d = 2.069$

Variable	Standardized regression coefficient b	Unstandardized regression coefficient B	95% Confidence Interval		p-value
			Lower	Upper	
% economically disadvantaged	–0.045	–0.042	–0.131	0.048	0.364
% URMS* **	–0.318	–0.215	–0.276	–0.154	<0.001
Physics test-taking ratio	–0.027	–0.142	–0.524	0.239	0.464
Chemistry test-taking ratio	0.042	0.158	–0.176	0.493	0.353
Biology test-taking ratio	–0.020	–0.060	–0.249	0.130	0.535
Algebra II test-taking ratio	–0.028	–0.103	–0.401	0.195	0.498
Chemistry performance* **	0.323	0.322	0.236	0.409	<0.001
Earth science performance	0.042	0.047	–0.044	0.138	0.313
Biology performance	–0.042	–0.055	–0.181	0.071	0.390
Geometry performance	0.036	0.037	–0.066	0.141	0.478
Algebra II performance*	0.105	0.133	0.014	0.252	0.028

Krakehl & Kelly. (2021).

Mediation Models Predicting Physics Performance

Testing Path	Independent Variable	Dependent Variable	Effect	Adj.R^2	df	F	β	B	SE(B)	95% CI
First Model*										
c	%URMS	Physics perf	Direct	0.408	662	456.472	–0.639	–0.432	0.020	–0.472, –0.392
a	%URMS	Chemistry perf	Mediated	0.361	662	375.244	–0.602	–0.408	0.021	–0.450, –0.367
b	Chemistry perf	Physics perf	Mediated	0.510	662	345.392	0.402	0.400	0.034	0.334, 0.467
c'	%URMS	Physics perf	Indirect	—	—	—	–0.397	–0.269	0.023	–0.314, –0.223
Second Model*										
c	%URMS	Physics perf	Direct	0.408	662	456.472	–0.639	–0.432	0.020	–0.472, –0.392
a	%URMS	Algebra II perf	Mediated	0.404	662	450.064	–0.636	–0.340	0.160	–0.372, –0.309
b	Algebra II perf	Physics TTR	Mediated	0.464	662	287.509	0.310	0.392	0.047	0.300, 0.483
c'	%URMS	Physics TTR	Indirect	—	—	—	–0.442	–0.299	0.025	–0.348, –0.250

*$p<0.001$; %URMS=schoolwide percentage of underrepresented minorities students; TTR=test-taking ratio; perf=performance (schoolwide passing percentage)

Krakehl & Kelly. (2020).

Conclusions

- State-level data sets provide an enormous amount of information on contextual factors that influence performance in the physical sciences.
- Physics performance is negatively predicted by urban school locale and socioeconomic status, but this effect is partially mediated by teaching experience.
  - Schools must work to retain experienced physics teachers, and universities must improve the preparation of preservice physics teachers.
- Physics performance is predicted by chemistry and algebra II performance.
  - Underrepresented students may perform better in physics if interventions are targeted in mathematics and chemistry.

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