EDUCATION COMMISSION OF THE STATES

POLICY BRIEF

NOV 2019

Accelerating Gains in K-12 Engineering Education

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States' efforts to incorporate technology and engineering into K-12 science instruction appear to be bearing fruit: More than five years after states began adopting K-12 science standards that feature technology and engineering, eighth graders have notched higher scores on a national assessment of those subjects.

This report presents Education Commission of the States' analysis of results from that assessment, the National Assessment of Educational Progress in Technology and Engineering Literacy (TEL), and the questionnaires that accompany it. It also explores state policies and practices that can continue boosting students' exposure to, and performance in, technology and engineering.

Dozens of states have departed dramatically from traditional K-12 science education by basing their science standards on the National Research Council's Framework for K-12 Science Education. The framework declares that "engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science."[1]

Unlike more traditional science, the framework argues, engineering always pursues practical applications. State standards that follow the framework challenge students to design solutions to real-world problems by tackling multiple steps — which include defining those problems, understanding constraints, brainstorming solutions, testing prototypes and revising designs based on outcomes.

Reforms to K-12 science education that embrace technology and engineering seem to be improving students' exposure to those critical fields.

Yet there are big gaps by race, ethnicity, family income and gender.

To close gaps and expand access, states can support better science assessments, curricula, teacher training and supplies for teaching technology and engineering.

The framework's definitions of technology and engineering are deeply rooted in this process of solving problems. Technology is "any modification of the natural world made to fulfill human needs or desires," and engineering is "a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants."[2] A pencil is an example of technology, and the process of designing an effective pencil is an example of engineering.[3]

States have embraced technology and engineering, because studies suggest that exposure to them can improve students' performance in math and science, heighten their interest in STEM careers and improve their grasp of problem-solving strategies. Advocates for science reform argue that the nation needs people with engineering design skills who can take on such daunting global challenges as finding new sources of energy, securing clean water or improving the nation's aging infrastructure.[4]

Results from the TEL assessment — and responses to accompanying questionnaires from administrators, teachers and test takers — suggest that state reforms are beginning to pay off: Schools are making technology and engineering a higher priority. Yet challenges persist: Most middle schoolers still have limited opportunities to experience the subjects, both in and out of school. In addition, there continue to be racial, economic and gender inequalities in access to instruction in technology and engineering, threatening to perpetuate similar inequalities in the STEM workforce. Fortunately, states can address these challenges by adopting such strategies as building innovative science assessments, supporting better curricula, training teachers and fostering equitable access to equipment and teaching materials.

More on the TEL Assessment and Contextual Questionnaires

The TEL assessment offers a singular opportunity to gauge the progress of recent science education reforms. The Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress, which guided the assessment's development, uses the same definitions of technology and engineering as the National Research Council framework that undergirds the science standards most states have adopted.

The assessment has been administered to eighth graders twice, making it possible to track changes since states first embraced new science standards. It was first administered in 2014, the year after states began adopting the Next Generation Science Standards (NGSS) or similar standards. The assessment was given again in 2018, after states had begun implementing the new standards, adopting new science assessments, supporting new curricula and promoting teacher professional development. A nationally representative sample of roughly 21,500 eighth graders participated in 2014, and 15,400 eighth graders participated in 2018.

Students, teachers and administrators also responded to questionnaires that addressed such topics as access to classes or clubs in technology and engineering, student engagement in engineering activities both in and out of schools, and students' attitudes towards technology and engineering. These questionnaires help researchers formulate a picture of eighth graders' technology and engineering experiences, both in and beyond school.

Evidence of Progress

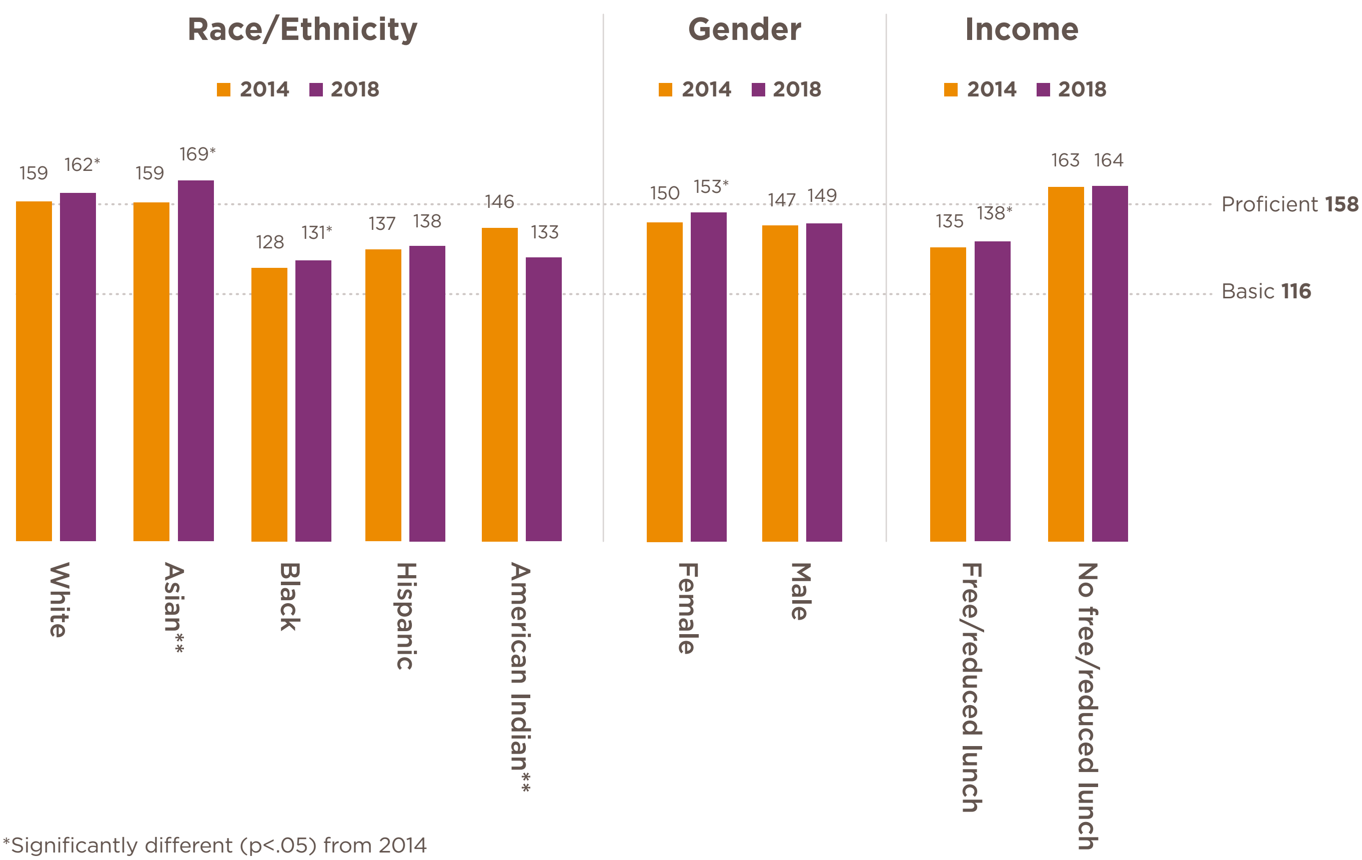
Education Commission of the States' analysis of TEL results from 2014 and 2018 finds that eighth graders are not only performing better but also gaining more exposure to technology and engineering in their schools. The baseline is admittedly low: A 2016 report on the 2014 TEL assessment found that students rarely engaged in technology or engineering activities at school. Still, changes since 2014 are significant and far-reaching.[5]

Eighth graders are performing better in technology and engineering than they did in 2014. The percentage of students scoring at the proficient level or higher rose from 42% to 45% between 2014 and 2018, a statistically significant change. The percentage reaching the advanced level also rose significantly, from 3% to 5%. The average scale score for all students also increased significantly from 149 to 151.

Most, but not all, groups of students saw improvements. Girls, white students, black students, Asian students and students who qualify for free or reduced-price lunch had significantly higher scores in 2018 than in 2014. *(See Figure 1.)*

FIGURE 1

Scores Rose for Most, but Not All, Groups of Students



*Significantly different (p<.05) from 2014

**Throughout this report, Asian students include Pacific Islanders, and American Indian students include Alaska Natives.

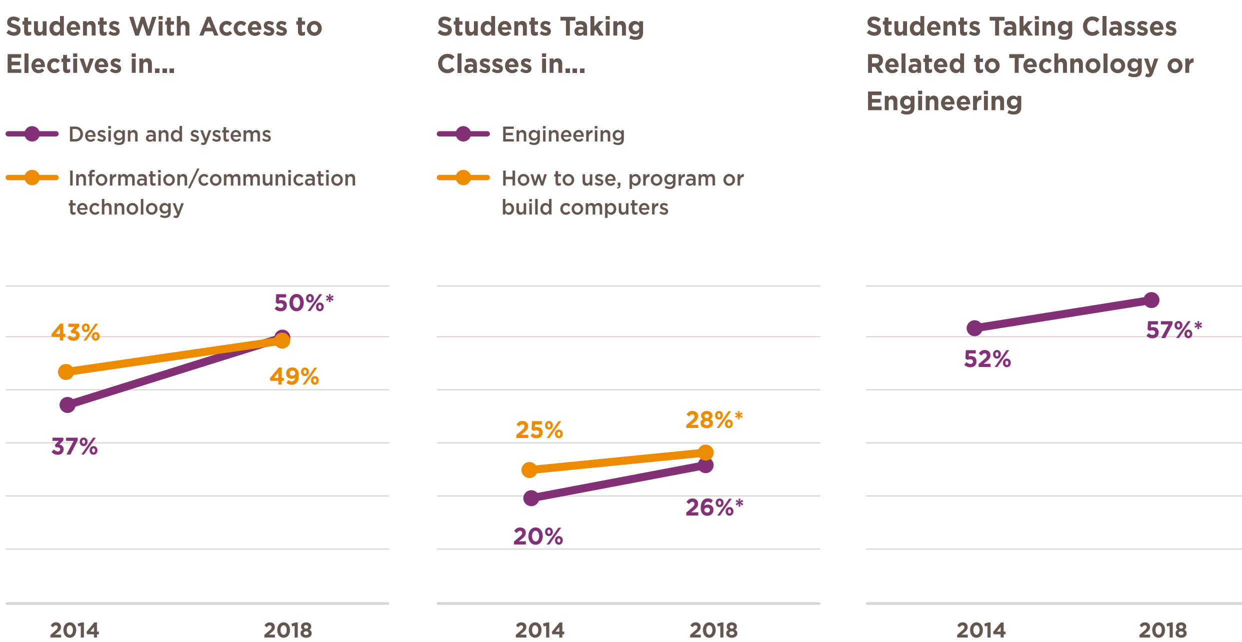
Students are more likely to have — and take advantage of — opportunities to learn technology and engineering in school. For example, the share of students in schools that offer electives on design and systems rose sharply from 2014 to 2018. Over the same period, there was a more muted increase in access to courses on information and communication technology.[6]

Enrollments improved as well. Students were more likely in 2018 than in 2014 to say they had taken engineering classes or classes on how to use, program or build computers.[7] The share of eighth graders who said they have ever taken any class relating to technology or engineering rose from 52% to 57%.[8] *(See Figure 2.)*

In 2018, students were also more likely to have access to clubs and competitions that focus on technology and engineering. That year, 90% of students attended schools that offered such clubs and competitions, up from 80% four years earlier.[9]

FIGURE 2

More Eighth Graders Have Access to, and Are Taking, Classes in Technology and Engineering



*Significantly different (p<.05) from 2014

A Coherent K-12 Strategy in Iowa

In **Iowa**, coordinated efforts among the governor, Legislature, business community and state education leaders have fostered a coherent strategy for supporting K-12 engineering opportunities across the state.

In 2012-13, the Iowa Governor's STEM Advisory Council launched the Iowa STEM Scale Up Program, an effort to expand effective STEM education programs statewide. Fueled by roughly $3 million in annual appropriations from the state's Legislature, the Scale Up initiative brought carefully vetted K-12 engineering programs to almost 90,000 students across the state by the time the Iowa State Board of Education adopted the Iowa Science Standards in August 2015.

That exposure to engineering programs — such as Project Lead the Way, Engineering is Elementary, A World in Motion and Engineering the Future — supported implementation of the newly adopted science standards. Since 2015, engineering programs in the Scale Up program have reached another 200,000 Iowa students across the state.

The leaders in business, education, and state and local government who make up the STEM advisory council bring vital perspectives about the needs of Iowa's economy and schools. Coordination between the council's regional hubs and the state's area education agencies has aligned the council's efforts with plans to implement Iowa's science standards.

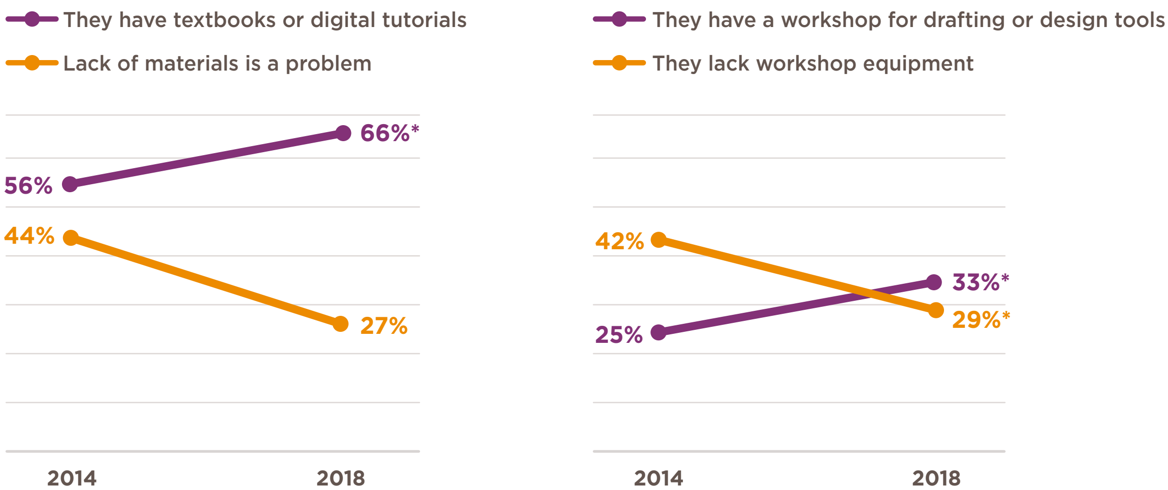
Teachers are more likely to have materials, facilities and professional development for teaching technology and engineering. The percentage of students attending schools that said they lacked instructional materials for technology and engineering fell precipitously between 2014 and 2018. Over the same period, the share of students whose schools reported having textbooks or digital tutorials on technology and engineering rose significantly. Similarly, students were more likely in 2018 to have access to workshops and equipment for such activities as drafting and design. *(See Figure 3.)*

FIGURE 3

Eighth Graders Have Greater Access to Materials and Equipment[10]

MATERIALS: **Students Whose Schools Say...**

EQUIPMENT: **Students Whose Schools Say...**



*Significantly different (p<.05) from 2014

Training Teachers on Open-Source Curricula

Some educators report having trouble finding and implementing effective materials that align with new science standards. States are considering open-source curricula that can ease this transition.

One organization, OpenSciEd, created open-source, full-course and NGSS-aligned instructional materials for middle school science classes. These materials are designed to help students make sense of phenomena or problems by training them to approach investigations "in the same manner as a scientist or engineer." All OpenSciEd courses were rated as high quality by a peer review panel overseen by Achieve, a nonprofit education reform organization in Washington, D.C.

Even though OpenSciEd materials are free, training teachers in the effective use of the new resources is not. **Michigan**, one of 10 OpenSciEd Partner States, allocated state funds granted to the Michigan Math and Science Leadership Network to "build up a group of professional learning experts who can train teachers on the curriculum." By making funds available for professional development to aid the adoption of NGSS-aligned materials, policymakers may be able to encourage more robust technology and engineering education instruction.

Professional development is on the rise, but the shortage of qualified teachers remains a challenge. Seventy-five percent of eighth graders in 2018 attended schools where at least some teachers received professional development in engineering or design, up from 60% in 2014.[11] The share of students in schools that see the lack of qualified teachers as a large or moderate problem has remained constant, however.[12] *(See Figure 4.)*

FIGURE 4

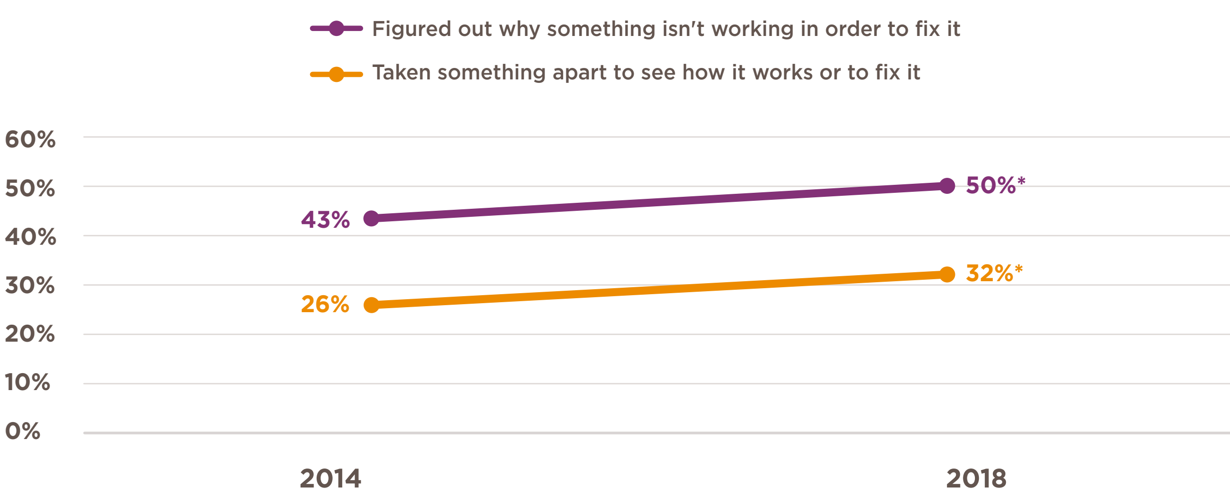
Almost Half of Eighth Graders Attend Schools Where Lack of Qualified Teachers Is a Large or Moderate Problem

In the aggregate, students are more likely to say their schools engage them in engineering practices. The TEL questionnaire includes questions about the kinds of activities students undertake in their classes. The results suggest that eighth graders are spending more time on common engineering practices like troubleshooting, taking things apart, or creating prototypes or models.[13] *(See Figure 5.)* Two other engineering activities — "building or testing a model to check a solution" and "using different tools, materials, or machines to see which are best for a given purpose" — showed no significant change in student engagement between 2014 and 2018.

The TEL questionnaire results reveal that students were more likely in 2018 than in 2014 to engage in several kinds of iterative problem-solving practices supported by research on effective learning. The years since states began embracing science reforms have witnessed significant changes in how students learn science. Rising scores on the TEL assessment suggest that these changes in schools may be having an impact.

FIGURE 5

Eighth Graders Are More Likely to Say They Have Done the Following at Least 3 Times in School[14]



*Significantly different (p<.05) from 2014

Cause for Caution

Even amid the evidence that technology and engineering are gaining traction in middle schools, advocates for K-12 engineering education have reason to be cautious. Students' engagement in engineering activities remains low in absolute terms, even if they are more likely to pursue such activities than they were in 2014. Education Commission of the States' analysis also reveals gaps in opportunity by gender, race, ethnicity and family income.

Students still spend limited time on key engineering activities. Asked whether they have figured out why something wasn't working in order to fix it, only half of eighth graders said they had done so at least three times in their school careers. Far less than half say that they have taken things apart or built models to solve problems at least three times.

In addition, the TEL questionnaire reveals little about the quality of students' technology and engineering experiences. More students take technology and engineering classes than in 2014, but the results offer few insights into the effectiveness of those classes. If students aimlessly tinker, troubleshoot or build, they probably will not meet any meaningful learning objectives.

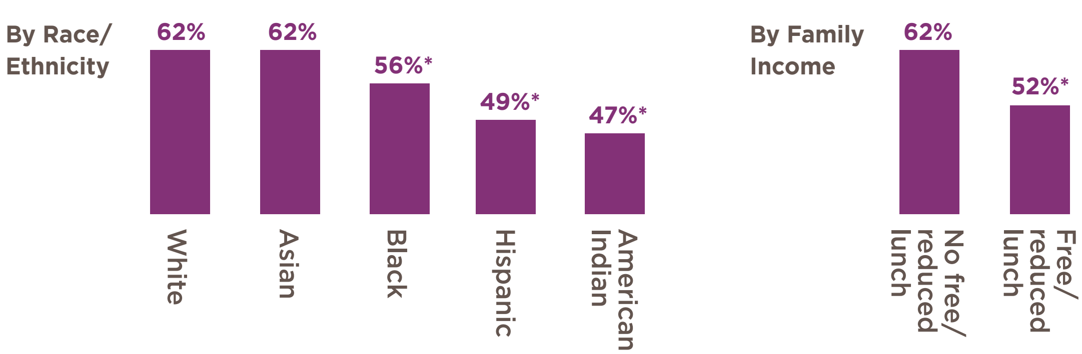
TEL data reveal racial, ethnic and income inequalities in access and participation. The TEL results suggest that inequalities in access to, and participation in, technology and engineering persist both in and out of schools. These inequalities foreshadow later gaps in the STEM workforce, where women and people of color are scarce in fields like engineering and computer science.

Black, Hispanic and American Indian students are less likely than white students to attend schools that require instruction in technology and engineering. Fifty-nine percent of white students — but only 48% of their black, Hispanic and American Indian peers — attend such schools.[15] It is not surprising, therefore, that black, Hispanic and American Indian students take technology and engineering classes at lower rates than white students do. For girls of color, access to opportunities is worse: American Indian girls, for example, are nearly twice as likely (68%) as white boys (35%) never to have taken a course in technology or engineering.

Similarly, students who are eligible for free or subsidized lunches — a proxy for poverty — are less likely than their wealthier peers to have taken such classes. *(See Figure 6.)*

FIGURE 6

Eighth Graders of Color and Those From Lower-Income Households Are Less Likely to Have Taken at Least 1 Technology or Engineering Course



* Significantly different (p < .05) from white or no free/reduced lunch.

Even so, the TEL data suggest that schools may mitigate some gaps in access and participation to technology and engineering. In their schools, for example, black students are as or more likely than white students to engage in engineering activities like troubleshooting and building models. Similarly, students who qualify for free or subsidized lunches are more likely than their wealthier peers to pursue some of these activities.

Outside of school, by contrast, black, Hispanic and low-income students are all significantly less likely than their white or higher income peers to engage in almost every engineering activity. *(See Figure 7.)*

Unfortunately, what happens outside of schools may still be more consequential than what happens in them. When asked who taught them most about building things, fixing things and how things work, 60% of eighth graders credited their families and 18% credited themselves. Only 15% pointed to teachers.[16]

Data from the TEL questionnaire suggest that, on average, students still receive little instruction in technology and engineering, despite encouraging gains in recent years. The shortage of teachers with qualifications in these subjects may limit the quality of whatever instruction students do receive. If young people must rely mostly on family or themselves to learn about technology and engineering, their success in these vital areas will be an accident of birth or circumstance.

Supporting Alaska Native Students

The **Alaska** Native Science and Engineering Program offers a continuum of programs from middle school through graduate school to prepare Alaska Natives for success in engineering and science careers. Federal government and state sources — including funds from the University of Alaska, the National Science Foundation and the U.S. Fish and Wildlife Service — made up 70% of ANSEP's budget in 2017.

For two weeks in the summer, ANSEP's Middle School Academy engages students in science and engineering activities, such as building computers and testing structures on earthquake simulation tables. Seventy-seven percent of Middle School Academy students complete algebra 1 by the end of the eighth grade, far exceeding the national completion rate of 26%.

ANSEP's five-week Acceleration Academy allows high school students to enroll in a science or engineering track and earn college credit. ANSEP reports that 95% of Acceleration Academy students advanced one course level or more in math or science each summer. External evaluators found that completing courses in the Acceleration Academy puts participants "on the path to college preparedness."

FIGURE 7

Eighth Graders of Color and Those from Lower-Income Households Are Least Likely to Have Done the Following 6 or More Times

TAKEN APART SOMETHING TO FIX IT OR SEE HOW IT WORKS

	Free/Reduced Lunch		Race/Ethnicity				
	Not Eligible	Eligible	White	Black	Hispanic	Asian	American Indian
In School	13%	15%	13%	21%	13%	15%	14%
Out of School	30%	27%	31%	30%	24%	28%	29%

FIGURED OUT WHY SOMETHING IS NOT WORKING IN ORDER TO FIX IT

	Free/Reduced Lunch		Race/Ethnicity				
	Not Eligible	Eligible	White	Black	Hispanic	Asian	American Indian
In School	22%	20%	21%	26%	18%	26%	18%
Out of School	39%	32%	40%	33%	28%	38%	28%

BUILT OR TESTED A MODEL TO SOLVE A PROBLEM

	Free/Reduced Lunch		Race/Ethnicity				
	Not Eligible	Eligible	White	Black	Hispanic	Asian	American Indian
In School	17%	13%	16%	17%	11%	19%	11%
Out of School	20%	15%	20%	16%	14%	20%	14%

USED DIFFERENT TOOLS, MATERIALS OR MACHINES TO SEE WHICH ARE BEST FOR A GIVEN PURPOSE

	Free/Reduced Lunch		Race/Ethnicity				
	Not Eligible	Eligible	White	Black	Hispanic	Asian	American Indian
In School	16%	14%	16%	17%	11%	19%	13%
Out of School	28%	20%	29%	20%	17%	27%	25%

■ Significantly higher than white or not eligible for free/subsidized lunch at $p<.05$

■ Significantly lower than white or not eligible for free/subsidized lunch at $p<.05$

Note: Green cells indicate a statistically significant advantage for students of color or students who are eligible for free or subsidized lunch. Orange cells, by contrast, indicate statistically significant gaps in favor of students who are white or from higher-income households.

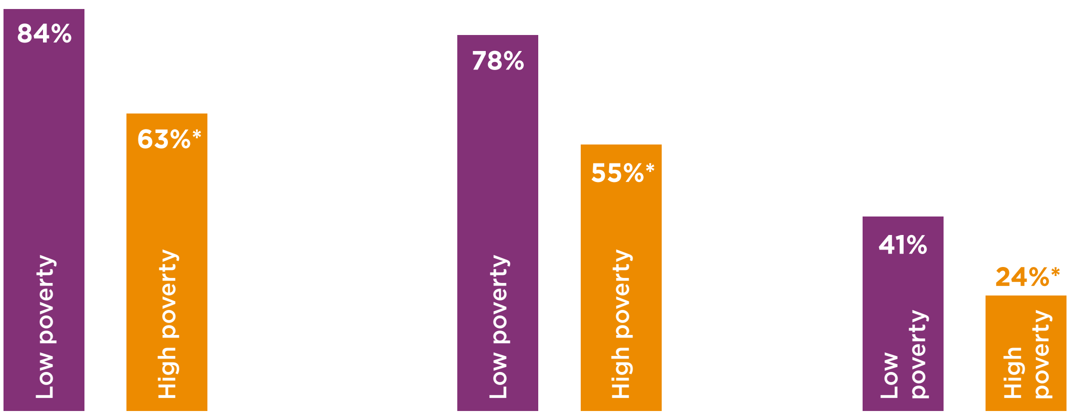
Students from lower-income households have inadequate access to support and resources for technology and engineering in their schools. Access to materials, equipment and teacher training in technology and engineering has improved since 2014, but inequality persists. Students in schools where most of the student body qualifies for free or subsidized lunches are much less likely than students in wealthier schools to have technology or engineering textbooks, workshops or teachers who received professional development in engineering. *(See Figure 8.)*

Lack of access to qualified teachers, facilities or materials can undermine the quality of courses or activities in technology or engineering and thus exacerbate the challenges that students in lower-income communities and schools endure.

FIGURE 8

Eighth Graders in the Highest Poverty Schools Have Lower Access to Trained Teachers, Materials and Equipment

Students with access to teachers who received professional development in engineering | Students with access to textbooks or digital tutorials in technology/engineering | Students with access to a workshop with design tools



* Significantly different (p < .05) from low poverty. Low poverty means schools where no more than 25% of students qualify for the National School Lunch Program. High poverty means schools where more than 75% of students qualify for the program.

Girls outscored boys, despite having less exposure to technology and engineering. Headlines about the most recent TEL assessment focused on its most eye-opening result: Girls significantly outscored boys for the second time in a row. On average, girls scored 153 — four points higher than boys — and bested them in five of the six content areas that make up the assessment.[17] These findings should lay to rest stubborn notions that males are better suited to technology and engineering than females.

Yet girls have less exposure to technology and engineering than boys do. They are less likely to have taken classes related to engineering or technology (53% vs. 62%) or to engage in engineering activities either in or out of school. *(See Figure 9.)*

FIGURE 9

Eighth Grade Girls Are Less Likely Than Boys to Say They Have Done the Following 6 or More Times

ENGINEERING ACTIVITY	GIRLS	BOYS
Taken something apart to fix it or see how it works (in school)	11%*	17%
Taken something apart to fix it or see how it works (out of school)	23%*	34%
Built or tested a model to solve a problem (in school)	14%*	16%
Built or tested a model to solve a problem (out of school)	14%*	21%
Figured out why something is not working in order to fix it (in school)	19%*	23%
Figured out why something is not working in order to fix it (out of school)	32%*	39%

* Significantly different ($p < .05$) from boys.

TEL's data may reflect a critical stage in the well-documented process by which girls drift away from STEM fields. Girls' interest in STEM fields declines faster than boys' as students move from elementary to middle school.

Research suggests that girls feel pressure to conform to traditional modes of feminine behavior. They worry they will confirm destructive stereotypes about women in STEM, and they avoid fields they perceive as masculine or inhospitable to women. The problem persists in high school and college; and it contributes to shortages in the STEM workforce, where women made up roughly 13% of engineers in 2018.

While the precise reasons why girls outscore boys are difficult to pin down, some plausible theories may offer insights on how to attract girls to STEM fields. The TEL assessment plays to girls' strengths by setting its engineering tasks in real-world scenarios for improving communities or helping people. (Indeed, TEL's definition of engineering as a means of meeting human needs and wants underscores this focus.)

Research on girls' and women's attitudes toward STEM fields finds that they are more likely than their male peers to aspire to careers that help people or make a difference in the world. Girls are too often discouraged by common portrayals of engineers and engineering that minimize engineers' benefits to society.

The design of the TEL's assessment, which places technology and engineering in their critical social contexts, should engage students of every group. Its vision of science education may be especially effective in bringing more girls into the fold.

Policy Considerations

The TEL results suggest that science education reform has begun to make its mark in four short years, but that states still have work to do. States can consider intentional policies and practices to ensure that every student receives an education in technology and engineering.

Align state science assessments with new science standards.

States are in the process of aligning science assessments with science standards that embrace technology and engineering. Such assessments are critical to ensuring that state standards have an impact on what schools teach.

States can emulate TEL's model for simulating the open-ended, multi-step tasks inherent in the engineering design process. Traditional multiple-choice assessments may not be well-suited to assessing students' performance on such open-ended tasks. The American Association for the Advancement of Science is developing a bank of more innovative multiple choice test items that align with NGSS, aim to assess students' conceptual understanding and test for common misconceptions.

TEL's scenario-based method is more expensive than tests that rely on multiple choice items, but advances in assessment technology may make scenario-based state tests more feasible. The federal Every Student Succeeds Act (ESSA) allows states to use federal funds to integrate technology and engineering into their state tests.

The U.S. Department of Education has also offered Competitive Grants for State Assessments to help states improve their assessment systems. Priorities for the 2019 grants, which totaled $17.6 million, included innovations "such as performance and technology-based academic assessments, computer adaptive assessments, projects or extended performance task assessments."

Offer teachers support in technology and engineering literacy.

New state science standards can present science teachers with a challenge. According to the 2018 National Survey of Science And Mathematics Education from Horizon Research, 54% of middle school science teachers have a degree in science, and only 10% ever took a college course in engineering. Just 12% feel very well prepared to teach students about defining engineering problems, and 14% feel very well prepared to teach them about developing possible solutions.

Current teachers need professional development on new science standards, associated curricula and hands-on instruction in technology and engineering. State and district education agencies can use federal funds from Title II of ESSA to support educators as they implement new courses, such as computer science and engineering.

Improve access to curricular and teaching materials.

States and districts can improve teachers' access to curricular and teaching materials that support technology and engineering. Curriculum developers have been creating such materials to meet demand since states began adopting NGSS.

K-12 science, technology and engineering curricula that have met standards for quality — such as those provided by OpenSciEd, Project Lead the Way, Engineering the Future and Engineering is Elementary — frequently offer professional development and materials or equipment to help teachers implement the curricula well.[18]

The proliferation of new materials can make it difficult for states, districts or teachers to identify those that are most effective. Several organizations offer free mechanisms for reviewing curricular materials. For example, EdReports.org is the only national nonprofit that employs teams of expert reviewers to rate how well science curricula align with NGSS, and its findings regularly appear in such media outlets as Education Week and Education Dive. In addition, Achieve, which helped facilitate the creation of the NGSS, developed the EQuiP Rubric, providing detailed criteria for measuring how well lessons and units measure up to those standards.

Developing State Assessments

According to the Center on Standards and Assessment Implementation, states require "a significant redesign of science assessments in order to fully meet the vision of NGSS." Such resources as the National Research Council's "Developing Assessments for the Next Generation Science Standards" and Achieve's "Criteria for Procuring and Evaluating High-Quality and Aligned Summative Science Assessments" offer states guidance on how to create and implement these new assessments.

California, which adopted NGSS in 2013, developed the California Science Test, a computer-based test combining stand-alone questions with performance tasks that require students to solve a series of related questions. To aid implementation of CAST and California NGSS, the California Department of Education created such resources as an informational video, a guide for parents and online practice and training tests for test administrators and students.

Kentucky, which also adopted NGSS in 2013, first administered the Kentucky Science Assessment in 2017-18. The assessment combines frequent classroom-embedded assessments with "formative 'through-course tasks,'" which are common performance tasks teachers must use periodically through the year to inform their teaching, measure student progress and foreshadow what will be expected in a final (summative) state assessment. Through-course tasks offer teachers a structured means of assessing students' mastery of science and engineering practices and addressing their needs throughout the year.

Supporting the Costs of Equipment and Materials in Massachusetts Schools

Since 2011, the **Massachusetts** Life Sciences Center has awarded 170 schools and organizations more than $16.5 million in state funds for equipment and supplies to support K-12 science education. The STEM Equipment and Supplies Program aims to help vocational-technical and low-income schools prepare students for careers in the life sciences. Industry partners in the state have contributed more than $1 million in cash and in-kind gifts.

Grants include funds for professional development to help schools and teachers ensure that the equipment supports vital learning goals. The most recent round of grants, announced May 2019, provided funding for equipment to support science and engineering, including biomedical engineering.

Improve access to facilities and materials that support technology and engineering, both in and out of schools.

New science standards that focus on technology and engineering require equipment and facilities that promote hands-on engagement in the engineering design process. State and local education leaders can fund the equipment and facilities themselves, but they can also collaborate with public and private partners who can donate equipment or equip public spaces as workshops or makerspaces.

Again, federal funds can help. States and districts can use funds authorized under ESSA and the Strengthening Career and Technical Education for the 21st Century Act to boost student access to materials, equipment and facilities that support hands-on engagement with technology and engineering.

Support out-of-school learning opportunities for more young people.

As noted earlier, results of the TEL questionnaire suggest that students are more likely to engage in engineering activities on their own time than in their classes. Support for effective after-school programs in technology and engineering can improve the quality and impact of those out-of-school activities.

Surveys of parents suggest that those who live in communities of concentrated poverty would welcome more and better after-school STEM programs for their children. Their communities are least likely to have access to engineering resources or professional engineers.

ESSA's 21st Century Learning Center Program has made more than $1 billion in federal funds available for out-of-school programs each year. Those funds can improve lower-income students' access to effective after-school programs.

Final Thoughts

Advocates for technology and engineering education can take heart that students are gaining more exposure to technology and engineering just five years after states began adopting sweeping science education reforms. Five years is not a long time for such reforms to take hold.

Yet such early gains can level off if states' reform efforts flag. Students' opportunities to learn about technology and engineering still depend largely on their race, ethnicity, family income, gender and family connections. States can sustain their progress by remaining dedicated to the long-term work of implementing their science standards. Reform at this scale will take time and staying power.

About the Authors

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Claus von Zastrow oversees efforts to improve statewide longitudinal data systems and provide state-by-state data on STEM education. He has held senior positions in education policy and research for more than 17 years and has spent much of that time helping diverse stakeholders find consensus on important education issues. Claus is dedicated to ensuring that state leaders have the information and guidance they need to make the best possible decisions affecting young people. Contact Claus at cvonzastrow@ecs.org or **202.844.6282**.

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ENDNOTES

[1] Since 2013, 20 states and the District of Columbia have adopted the NGSS, which a consortium of states created to align with the National Research Council's framework. Another 24 states have adopted other science standards based on the same framework.

[2] The National Research Council's framework takes pains to distinguish its definition of technology from more common definitions: "[W]e broadly use the term technology to include all types of human-made systems and processes — not in the limited sense often used in schools that equates technology with modern computational and communications devices." The National Research Council adopts verbatim definitions used by a separate but related framework, the Technology and Engineering Literacy Framework for the 2014 National Assessment of Educational Progress. In keeping with these definitions, the TEL assessment does not assess students' coding or computer science skills.

[3] The framework presents technology and engineering as skills and knowledge everyone needs to master, rather than vocation skills for budding engineers or software developers. People literate in technology and engineering may not be qualified to design software or rocket engines, but they can understand "how science and engineering pertain to real-world problems" and "apply their scientific knowledge to engineering design problems once this linkage is made."

[4] Employers prize skills in technology and engineering. In surveys, they say that they value problem-solving skills more highly than specific technical skills. They report that such skills make employees more innovative, independent, resilient in the face of challenges and prepared to deal with ambiguity.

[5] All gaps and changes noted in this report are statistically significant at p<.05 unless otherwise noted. All data are for national public schools.

[6] In the school questionnaire, the questions about engineering electives read as follows: Prior to or in eighth grade, how are each of the following areas addressed in your school's curriculum?

- Design and Systems (the nature of technology, the engineering design process by which technologies are developed, or basic approaches to dealing with everyday technologies, including maintenance or troubleshooting) Elective.
- Information and Communication Technology (for example, computers; software learning tools; networking systems and protocols; handheld digital devices; other technologies for facilitating creative expression) Elective.

Possible answers were yes or no.

[7] There was no significant change in the percentage of students taking industrial technology classes or other technology-related classes.

[8] When asked to identify the technology- and engineering-related courses they had taken in or before eighth grade, students had the following choices: Industrial technology; Engineering; Courses on using, programming, or building computers; Other technology-related classes; None of the above. The question on using, programming or building computers reads: "any class that involves learning to use, program, or build computers."

[9] The question in the school questionnaire reads: "In your school, prior to or in eighth grade, what percentage of eighth-grade students has taken advantage of the following school-sponsored resources during or after school? Clubs, competitions, exhibits, etc., related to some aspect of technology and engineering." Possible responses: Not provided; 0-5%; 6-20%; 21-50%; Over 50%.

[10] The chart on the left shows:

- The percentage of students in schools that reported that, to a large or moderate extent, "the lack or inadequacy of instructional materials (for example, textbooks, computers, software)" hindered their school's "capability to provide instruction in technology or engineering concepts."
- The percentage of students in schools that responded "yes" to the following question: "This year in your school, are the following resources available to teachers for teaching or professional development? Textbooks or digital tutorials related to technology or engineering."

ENDNOTES

The chart on the right shows:

- The percentage of students in schools that reported that "the lack or inadequacy of laboratory or workshop equipment" hindered their "capability to provide instruction in technology or engineering concepts" to a moderate or large extent.
- The percentage of students whose schools reported having a "Workshop or laboratory for drafting or design tools (for example, computer-aided design [CAD], systems analysis)" available "to teachers for teaching or professional development?"

[11] The question asks schools, "In the past two years, what percentage of teachers in your school has participated in professional development in content, curriculum, or pedagogy related to engineering design." Possible answers include: Not applicable; 0%; 1-25%; 26-50%; 51-75%; Over 75%; I don't know.

[12] The question asks teachers, "To what extent is your school's capability to provide instruction in technology or engineering concepts hindered by the lack of qualified teachers trained in technological or engineering content?" Possible responses include: Not at all; Small extent; Moderate extent; Large extent.

[13] The 2018 Framework for the TEL assessment includes similar activities in its description of "what should be expected of students in terms of their knowledge and skills with technology." For example, eighth graders should be able to "examine a product or process through reverse engineering by taking it apart step by step to identify its systems, subsystems, and components, describing their interactions, and tracing the flow of energy through the system." They should be adept at "diagnos[ing] a problem in a technological device using a logical process of troubleshooting" and "develop[ing] and test[ing] various ideas for fixing it." In addition, they should be able to "design and build a simple model that meets a requirement, fix it until it works (iteration), test it, and gather and display data that describe its properties using graphs and tables."

[14] Possible responses to each question were: Never; Once or twice; Three to five times; More than five times. The chart shows the percentages of students who have engaged in those activities at least three times in their entire school careers, leading up to and including eighth grade.

[15] The question reads, "Prior to or in eighth grade, does your school require any technology or engineering instruction to students?" (school-reported)

[16] Schools made minor inroads between 2014 and 2018: The influence of teachers rose by small, but statistically significant, increments in both areas. Between 2014 and 2018, the share of students saying teachers taught them most about key engineering practices rose from 13% to 15%. In technology, it rose from 25% to 26%.

[17] TEL's six assessment areas are: Technology and Society, which "deals with the effects that technology has on society and the environment as well as the ethical questions raised by those effects;" Design and Systems, which "focuses on the nature of technology and the processes used to develop technologies, as well as basic principles for dealing with everyday technologies;" Information and Communication Technology, which "covers software and systems used for accessing, creating, and communicating information, and for facilitating creative expression;" Understanding Technological Principles; Developing Solutions and Achieving Goals; Communicating and Collaborating. Girls significantly outscored boys in every area but Design and Systems.

[18] As noted earlier, OpenSciEd's courses received a high-quality rating from a peer review panel overseen by Achieve, a nonprofit education reform organization. Project Lead the Way, Engineering the Future and Engineering is Elementary received "accomplished" ratings from STEMworks, an honor roll of effective STEM education programs overseen by WestEd, a nonprofit evaluation and research firm.

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