White Paper

mySci Impact: Student Outcomes Overview

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Introduction

The release of the Next Generation Science Standards (NGSS) in 2013 marked a turning point for K-12 science education. Moving away from didactic approaches that prioritize memorization of facts, the NGSS emphasizes critical thinking, problem solving, and engaging in scientific practices such as investigation, data analysis, modeling, and evidence-based argumentation. As of 2023, 20 states adopted the NGSS, and an additional 24 states modeled their own science standards after the NGSS (National Science Teaching Association, n.d.). In 2016, Missouri released the Missouri Learning Standards (MLS) for science based on the NGSS. Like the NGSS, the MLS diverges from previous approaches to K-12 science education, shifting the burden placed on teachers to change their classroom practices to schools to provide materials, supplies, and support. Despite the increased need for time and materials to meet more rigorous standards, schools across the country have decreased the resources allocated to and time spent on science instruction, which has negative implications for student achievement (Blank, 2013; Smith, Trygstad, & Banilower 2016).

mySci was developed by the Institute for School Partnership (ISP) at Washington University in St. Louis to increase access to high-quality science learning for every student. Partnering with local experts from the St. Louis Science Center, the St. Louis Zoo, and the Missouri Botanical Gardens, the ISP leveraged existing relationships with educators to build the program. As a design-based implementation research-practice partnership (RPP), the mySci program is regularly updated to reflect advances in scientific research, best practices from the field of education, and partner educator contexts. The interactive learning opportunities in mySci are designed to engage students and the full mySci program works to reduce barriers for teachers and schools so that all students can access high-quality science instruction.

The mySci program includes NGSS and MLS-designed K-8 science units as well as kits that include all the materials needed for hands-on and exploratory classroom activities. Each mySci K-8 unit follows the 5E learning cycle[1] and incorporates assessment and design challenges designed to cover approximately one academic quarter, with four units offered per K-4 grade level, and five for grades 5-8. Providing ongoing curricular, pedagogical, and material support to implement the MLS, mySci bolsters student learning tailored to district-specific needs. Each year, more than 100,000 students in the St. Louis region learn science using mySci.

[1] Engage, Explore, Explain, Elaborate, Evaluate

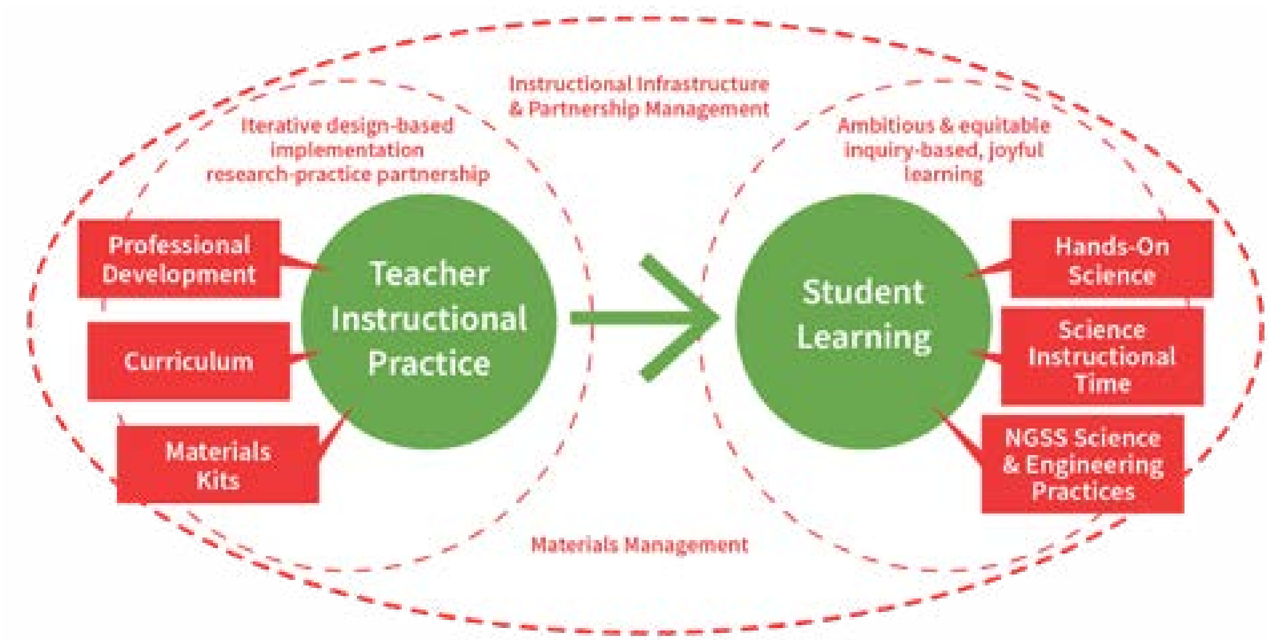
mySci Theory of Action

One of mySci's primary goals is to increase student achievement in science. To accomplish this, the program provides teachers and schools with four types of support and resources:

1. **Inquiry-based curricular resources** designed to support teacher learning and facilitate the use of the 5E instructional model;
2. Kits with all of the **materials for hands-on science activities and investigations**, delivered to schools quarterly and collected from teachers to be refurbished and re-used; and
3. **Professional development** tailored to the curriculum, blending science content with practical classroom application;
4. **Active partnership** management and infrastructure consultation with school and district administrators to ensure the practical context-specific translation of curriculum, kits, and professional learning.

These program activities are implemented as a partnership between mySci instructional specialists and school or district administrators to create a supportive instructional infrastructure which allows for sustainable implementation with integrity (Penuel, 2019). These facets of the program improve teacher practice and performance leading to improved student learning and science achievement.

Each component of the mySci program has a basis in research on best practices in science teaching and learning.



Curricular Resources

mySci consists of 25 K-5 units and 15 middle school modules. Written curricular resources include lesson plans, student journals, assessments, and lesson slides, as well as tutorials and background information to support teacher learning and guide the use of mySci materials and activities. mySci also provides video mini-lessons for K-5 students, lab videos for middle school students, and various other virtual learning tools. Teachers access the resources through the mySci Partners website, and all written materials are available in Google Docs, so teachers can edit and adapt as needed. mySci is intentionally designed to support rigorous, equitable science instruction following the Framework for Equitable Lesson Development (Ruggirello & Brockhouse, 2023). The Institute for School Partnership which houses mySci is based within Washington University in St. Louis which allows mySci to leverage and incorporate cutting edge science and engineering research through faculty partnerships.

All mySci lessons follow the 5E learning cycle, an inquiry-based approach to science instruction. In inquiry-based learning, students act like scientists: rather than learning about science concepts directly from a textbook or teacher, students form and test hypotheses about scientific phenomena and conduct their own investigations in a process that allows them to discover causal relationships (Pedaste et al., 2015). A popular approach to inquiry-based teaching involves the use of instructional models, which are designed to systematically guide students and teachers through investigations and activities. mySci uses the 5E instructional model, which guides students through five phases of learning and discovery: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). Studies have found that use of the 5E model is more effective than traditional modes of instruction at increasing student mastery of science concepts (Akar, 2005; Guzzetti et al., 1993), academic achievement (Anil & Batdi, 2015), use of scientific reasoning (Boddy et al., 2003), and improving student interest in and attitude towards science (Akar, 2005; Boddy et al., 2003; Tinnin, 2000).

To aid teachers in adopting 5E instruction, mySci embeds teacher support in its curricular materials. In addition to providing background information on science concepts, the written materials offer tools for promoting student discussion, and highlights opportunities for feedback, formative assessment, and activating students' prior knowledge. These classroom practices are among the most highly associated with student achievement (Hattie, 2008).

Researchers have long argued that curriculum materials which support teacher learning, also called educative curriculum materials (ECM), have the potential to improve both teacher practice and students' science learning and achievement (e.g. Ball & Cohen, 1996; Davis & Krajcik, 2005). Using the principles of educative curriculum, mySci aims to develop teachers' understanding of the subject matter, anticipate student misconceptions, and support adaptation by explaining the rationale behind activities and design choices (Davis & Krajcik, 2005; Grossman & Thompson, 2008). Evidence supports that ECMs improve teacher knowledge, instructional practice, and student performance in science (e.g. Cervetti, Kulikowich, & Bravo, 2015; Arias, Smith, Davis, Marino, & Palincsar, 2017). Curricular resources embedded with teacher supports are associated with student gains in content knowledge and increased understanding of science practices (Roblin, Schunn, & McKenney, 2018).

Kit Materials and Hands-on Science

Hands-on activities are central to the mySci program. As students explore materials and conduct investigations, they clarify their understanding, develop their abilities, and reconstruct science concepts (Bybee et al., 2006). To ensure that teachers can carry out the hands-on activities in each lesson, mySci provides kits containing the necessary materials for the activities in each unit or module. Kit materials range widely, including things like seeds and soil for growing plants, sugar cubes and water droppers for modeling cave formation, owl pellets for dissection, plasma globes and cathode tubes for exploring non-contact forces, and more. mySci delivers kits to schools on a quarterly basis, retrieves and refurbishes used kits for future use, and collects teacher feedback on the quality and use of kit materials.

mySci's kit activities allow students to construct science knowledge from their own experiences. Educational psychologists have long argued that the construction of knowledge from experience is key to the learning process, and allows learners to achieve a deeper understanding of concepts than traditional modes of instruction like lectures or textbooks (e.g. Piaget, 1952; Vygotsky, 1978). Numerous studies have shown that hands-on activities promote better retention of science information and higher scores on science assessments when compared to direct instruction (e.g. Stohr-Hunt, 1996; Scruggs, Mastropieri, Bakken, & Brigham, 1993) and lead to higher science achievement among students with disabilities (McCarthy, 2005). A meta-analysis of 57 controlled studies found that activity-based science instruction was associated with gains in creativity, intelligence, language, and mathematics, with disadvantaged students deriving particular benefit (Bredderman, 1983). The provision of kit materials can augment the benefits of hands-on activities: in one study, students in classrooms using kits had higher achievement scores, and learned science topics in greater depth, than those in non-kit classrooms (Young & Lee, 2005). The use of hands-on activities is particularly effective when paired with classroom discussion. For example, on the most recent National Assessment of Educational Progress (NAEP), 4th graders who frequently did hands-on activities in science class and talked about the results of those activities scored higher in science than those who rarely did hands-on activities, or rarely discussed the results of activities (U.S. Dept. of Education, 2015).

Tailored Professional Development and Embedded Professional Learning

mySci's professional development (PD) program aims to instruct teachers in the use of mySci curricular resources and kit materials, improve their understanding of NGSS concepts and practices, and increase their sense of self-efficacy around science teaching. To accomplish these goals, mySci partners with districts to customize multi-year professional learning plans. mySci offers workshops focused on kit materials and activities, NGSS practices, and other science or pedagogical topics; job-embedded PD, including instructional coaching and support for teacher professional learning communities (PLCs); teacher leadership development; support for virtual teaching; and opportunities for networking and collaboration. mySci instructional specialists typically return to a district several times per year to offer sustained support and feedback (though the exact frequency varies depending on a district's needs and circumstances).

The design of mySci's professional development program reflects an emerging consensus about features that best support teacher learning. Effective PD is content-focused, of sustained duration, and features opportunities for active learning, coaching, collaboration, modeling, feedback, and reflection (Darling-Hammond, 2017). mySci's content-focused PD centers on curriculum materials and NGSS practices, which has been shown to improve both teacher practice and student science achievement (e.g. Jackson & Ash, 2012; Taylor, Getty, Kowalski et al., 2015). Many of mySci's PD offerings also incorporate analysis of instruction, student work, and issues from teachers' own practice. Such reflective coaching and feedback helps teachers apply ideas in their classrooms and discuss challenges and successes as they do so. Research has shown that PD which includes coaching and instructionally-linked feedback is associated with stronger gains in teacher performance and student academic achievement than PD which does not focus on a teacher's instruction (e.g. Gallagher et al., 2017; Landry et al., 2009). Aside from improving instruction, another important goal of mySci PD is improving teacher self-efficacy, or the belief of teachers in their ability to positively affect students (Hattie, 2008). Comprehensive PD programs like mySci are associated with increases in teacher persistence, motivation, self-efficacy (e.g. Yoo, 2016; Powell-Moman & Brown-Schild, 2011); increases in teacher self-efficacy are associated with greater student learning and achievement (Hattie, 2008).

Implementation and Research Partnership

The challenges educators navigate are varied and unique to their contexts. In order to address those challenges, mySci collaborates directly with teachers, coaches, and administrators who are doing the daily work of educating children. As a research-practice partnership (RPP), mySci is continuously and actively designed to effect practitioner-led problem-focused change with emphasis on supporting and studying implementation at scale. Blending the methodological and theoretical approaches of design-based implementation research (DBIR) (Fishman et al., 2013) and improvement science (Bryk et al., 2015), the program is structured to include educators as researchers through systematic inquiry to iterate on and disseminate findings through the curricular resources, kits, and professional development directly (Penuel & Gallagher, 2017). Teachers share feedback and reflections on the program formally through surveys, interviews, and focus groups, as well as serving as paid curriculum writers and consultants.

Additionally, mySci partnership managers hold regular, ongoing meetings with every partner school or district to support program implementation. These partnership meetings cover the practical concerns around kit delivery and pick-up or PD topics and scheduling, but also serve as a vital space for instructional infrastructuring research, capacity building, and relationship building. These supportive partnership conversations make use of empathy interview methods and explicitly foreground racial justice to develop research goals and promote democratization of evidence (Nelsestuen & Smith, 2020; Ruggirello, et al., 2023). This partnership forward approach upends the power asymmetries between universities and K-12 educators that can hinder RPP success (Diamond, 2021) and is essential to the program.

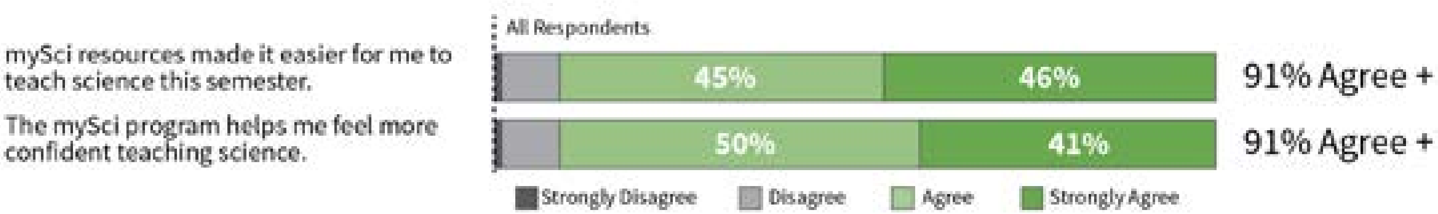
mySci impact on Schools and Teachers

In order to monitor and support the integrity of implementation as well as in internal continuous quality improvement efforts, mySci collects and analyzes various forms of data from teachers and students. This includes pre- and post-test scores on mySci unit assessments; scores on the Missouri Assessment Program (MAP) science test, administered annually to 5th and 8th grade students; professional development feedback surveys, administered to teachers in attendance at every professional development session; and an annual implementation survey distributed to all mySci teachers. In the implementation survey, teachers are asked to complete the Science Instructional Practices Survey (SIPS), a tool which measures teacher use of NGSS-aligned practices such as modeling, scientific argumentation, and data collection and analysis (Hayes, et al., 2016).

Improved Outlook on Science Teaching

Evidence collected thus far strongly suggests that mySci's professional development, curriculum, and kit resources help teachers feel better prepared to teach science. In a teacher survey from spring 2022, teachers overwhelmingly reported that the mySci program increases their confidence: 91% of mySci teachers agreed that the mySci program helps them feel more confident teaching science, and 91% agreed that mySci makes it easier for them to teach science (n=790)[2]. Because feelings of confidence are an important component of self-efficacy (Bandura, 1978), ongoing evaluation efforts provide a strong foundation for future research seeking to more directly show the impact of mySci on teacher self-efficacy.

Teacher Opinions About mySci



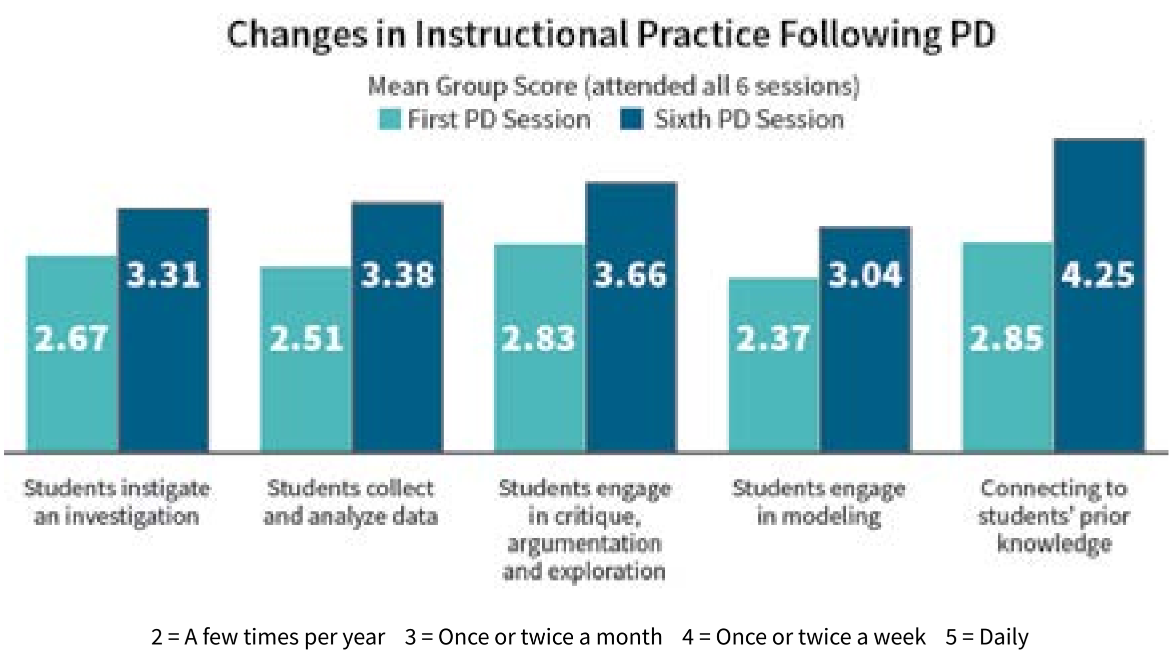
mySci professional development is well received by teachers and administrators, and teachers believe that mySci PD will help their teaching practice. During the 2021-2022 school year, mySci received 813 responses to its PD feedback survey, with 98% of teachers reporting that the PD session they attended was valuable to their professional growth[2].

[2] "This session was valuable to my professional growth." Strongly Agree (75%),Somewhat Agree (23%), Somewhat Disagree (2%), Strongly Disagree (1%).

Qualitative data also indicates that teachers believe mySci enhances their teaching practices, providing critical supports to enhance joyful, inquiry-based science learning. Teachers provide a wide variety of encouraging comments through regular surveys. A first grade teacher at Momentum Academy said, *"If I didn't have MySci I don't know what I would do! Thank you for sending all materials necessary and linking to great videos. Many of my students write in their journals about science being their favorite and what they're learning, so it encourages me."* Kindergarten teachers from Ferguson Florissant and Wentzville school districts said, *"I didn't particularly care for teaching science until our district adopted MySci. I now enjoy it and love watching my kinders make discoveries"* and *"I have really enjoyed the MySci program and feel even more confident using it for the second year. It's so great and easy to implement! My kids cheer when I say it's time for science."* A fourth grade teacher from the Hazelwood School District said, *"Overall, MySci has made me a better science teacher."*

Increased Use of NGSS Classroom Practices

In addition to feedback on professional development and curriculum implementation, mySci uses the evidence-based teacher Science Instructional Practices Survey (SIPS) to examine the impact of the mySci program (Hayes et al., 2016). During the 2021-2022 school year, 3rd, 4th, and 5th grade teachers who had attended mySci professional development sessions reported more frequent use of the NGSS Science and Engineering Practices, with statistically significant findings for these practices: Asking questions & defining problems, Planning and carrying out investigations across grade bands, Constructing explanations & designing solutions, Engaging in argument from evidence. In an investigation of mySci adoption in one district during the 2020-2021 school year, participants completed the SIPS once at their first mySci professional development session and again after their fourth session. These teachers demonstrated statistically significant increases in these NGSS Science and Engineering Practices: Developing and using models, Planning and carrying out investigations, Analyzing and interpreting data, Constructing explanations and designing solutions, and Engaging in argument from evidence.

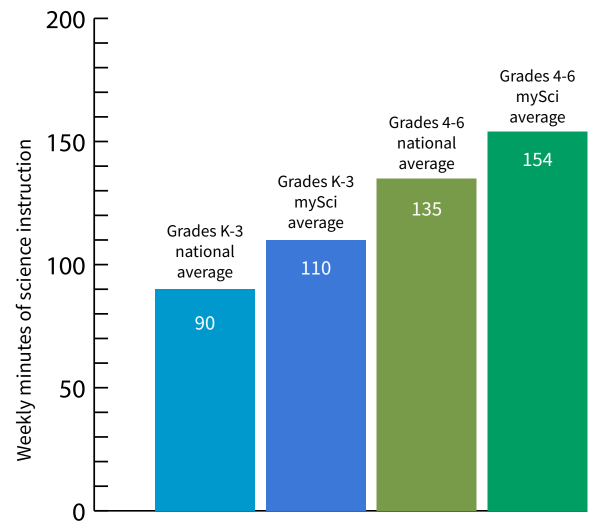


2 = A few times per year 3 = Once or twice a month 4 = Once or twice a week 5 = Daily

More Classroom Time Spent on Science

Research has shown that increased instructional time is associated with increases in student learning across all subject areas, especially at the elementary level (Fisher et al, 2015; Curran & Kitchin, 2019). In 2022, Kindergarten - 3rd grade teachers who use mySci report spending an average of 116 minutes per week compared to an average 90 minutes reported nationally, and 4th - 6th grade teachers who use mySci report spending 162 minutes per week compared to the national average of 135 minutes (Banilower et al., 2018).

Weekly Minutes of Science Instruction National v mySci

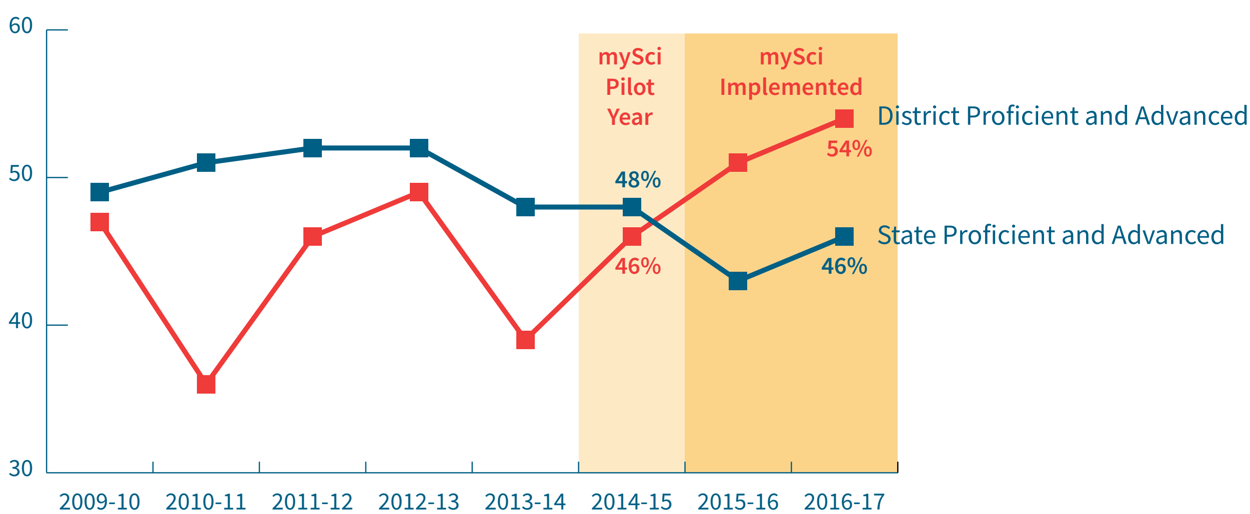


Data from:
National Survey of Science and Mathematics Education Horizon Research, 2018 and mySci teacher survey, May 2021 (N=459)

mySci impact on Students

mySci partners with districts to evaluate how effectively the program prepares students for science learning and achievement under the MLS for science. In one large, suburban, racially diverse mySci district, student achievement on the 5th Grade Science MAP lagged behind the state average prior to mySci implementation from the 2009-2010 school year through the 2014-2015 school year with more district students performing at the Below Basic level than state-wide and fewer district students performing at the Proficient or Advanced levels. Beginning in the first full year of K-5 mySci implementation in 2015-2016, this trend reversed, with gains at the district level in students at the Proficient and Advanced levels and corresponding decreases in students performing at the Below Basic level overall and in comparison to the state.

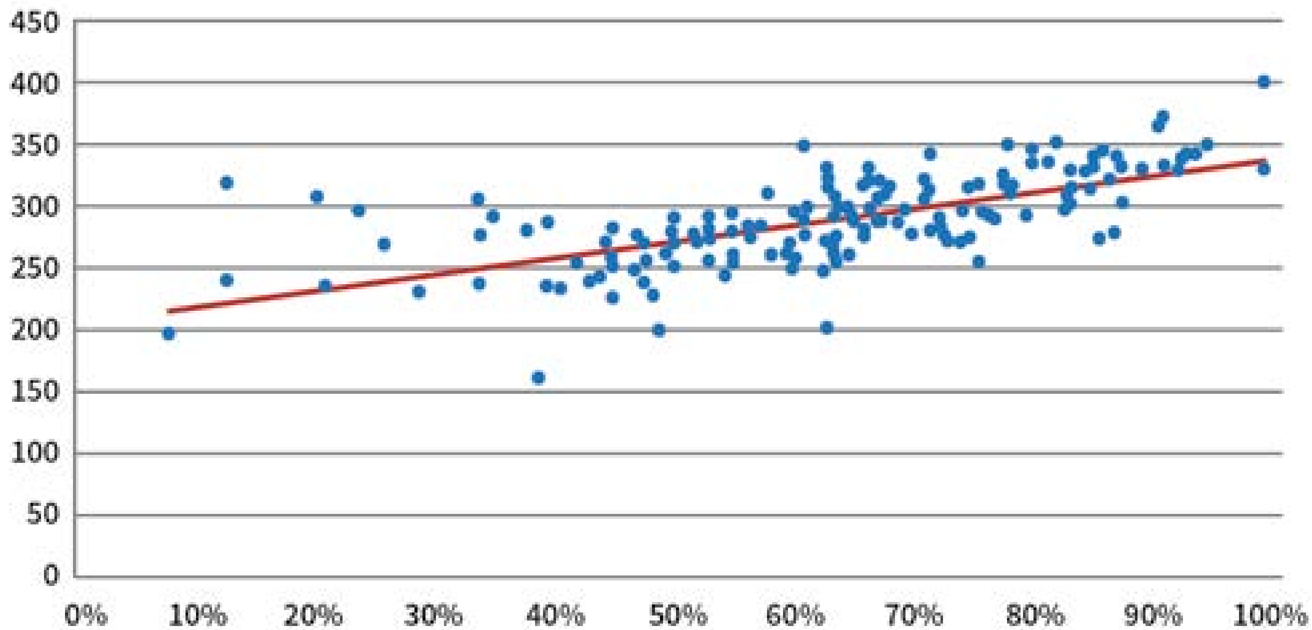
The share of proficient and advanced students has exceeded state levels since mySci start in 2015-16



During the 2017-2018 school year, Missouri's Department of Early & Secondary Education (DESE) rewrote the Science MAP and did not release achievement data, and the 2018-2019 Science MAP scores are not comparable to previous years. The 2019-2020 state testing was canceled due to the COVID-19 pandemic. Previous analysis had shown strong correlation between mySci unit post-test scores and 5th Grade Science MAP scores. Pearson correlation with the 2015-2016 5th Grade Science MAP and mySci unit post-tests ranged from r = .539 to r = .603 and were statistically significant in two-tailed testing at $p <= 0.01$ (n=379 students). This analysis was recreated in a different mySci district to assess the correlation between the mySci post-test scores and the updated 5th Grade Science MAP given in 2018-2019. Correlations between the students' scores remained high after the test update with Pearson r values ranging from r = 0.609 to r = 0.661, statistically significant in two-tailed t-testing at $p<=0.01$ (n=149 students). The correlation between the mySci assessment scores and state testing demonstrate the continued efficacy of the mySci curriculum.

5th Grade Science MAP Score by mySci Post-Test Assessment Score

2018-2019



This graph shows students' MAP scores plotted against the average of their mySci post-assessment scores in one mySci partner district. The coefficients of correlation across their four mySci 5th Grade unit post-test scores and their 2018-2019 5th Grade Science MAP score range from r=0.609 to r=0.661 (p<=0.01, n=149 students).

Conclusion

mySci is intentionally designed in partnership with educators to provide students with the hands-on, engaging learning that leads to more equitable academic achievement. The curricular materials follow these best practices and multiple mySci units have been awarded the Next Generation Science Standards (NGSS) Design Badge as part of a rigorous peer-review process to identify high-quality science instructional resources. As a program, mySci manages the materials and provides aligned professional development so that teachers can more easily implement lessons and focus on their students' needs. In addition to aligning curriculum, kits, and professional learning, mySci works in partnership with schools to support the instructional and materials management infrastructure necessary to support teachers. Taken as a whole, the mySci program works to make it easy for every teacher to confidently teach science in alignment with the NGSS practices and standards, so that every student has the opportunity to experience the hands-on joy of science.

References

Achieve (2019). The State Of State Science Education Policy: Achieve's 2018 Science Policy Survey. In Taking Science to School. National Academies Press. https://doi.org/10.17226/11625

Akar, E. (2005). EFFECTIVENESS OF 5E LEARNING CYCLE MODEL ON STUDENTS' UNDERSTANDING OF ACID-BASED CONCEPTS. THESIS MIDDLE EAST TECHNICAL UNIVERSITY. Retrieved from https://doi.org/10.1080/17461391.2020.1733672%0Ahttp://www.efdeportes.com/efd48/trein2.htm%0Ahttp://seer.uftm.edu.br/revistaeletronica/index.php/aces%0Ahttp://www.tandfonline.com/doi/abs/10.1080/02701367.2004.10609174%5Cnhttp://insights.ovid.com/crossref?

Anil, Ö., & Batdi, V. (2015). A Comparative Meta-Analysis of 5E and Traditional Approaches in Turkey. Journal of Education and Training Studies, 3(6). https://doi.org/10.11114/jets.v3i6.1038

Arias, A. M., Smith, P. S., Davis, E. A., Marino, J. C., & Palincsar, A. S. (2017). Justifying predictions: Connecting use of educative curriculum materials to students' engagement in science argumentation. *Journal of Science Teacher Education*, 28(1), 11–35. https://doi.org/10.1080/1046560X.2016.1277597

Ball, D. L., & Cohen, D. K. (1996). Reform by the Book: What Is—or Might Be—the Role of Curriculum Materials in Teacher Learning and Instructional Reform? Educational Researcher, 25(9), 6–14. https://doi.org/10.3102/0013189X025009006

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review, 84(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Blank, R.K. (2013). Science Instructional Time Is Declining in Elementary Schools: What Are the Implications for Student Achievement and Closing the Gap? Science Education, 97(6), 830-847. DOI 10.1002/sce.21078

Boddy, N., Watson, K., & Aubusson, P. (2003). A trial of the Five Es: A referent model for constructivist teaching and learning. Research in Science Education, 33(1), 27–42. https://doi.org/10.1023/A:1023606425452

Bredderman, T. (1983). Effects of Activity-Based Elementary Science on Student Outcomes: A Quantitative Synthesis. Review of Educational Research, 53(4), 499-518. Retrieved February 23, 2021, from http://www.jstor.org/stable/1170219

Bryk, A.S., Gomez, L. M., Grunow, A., & Mahieu, P.G. (2015). Learning to improve: How America's schools can get better at getting better. (Fifth printing). Harvard Education Press.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins, effectiveness, and applications, Colorado Springs: BSCS.

Cervetti, G. N., Kulikowich, J. M., & Bravo, M. A. (2015). The effects of educative curriculum materials on teachers' Use of instructional strategies for English language learners in science and on student learning. *Contemporary Educational Psychology*, 40, 86–98. https://doi.org/10.1016/j.cedpsych.2014.10.005

Darling-Hammond, L., Hyer, M.E., & Gardner, M. (2017). Effective Teacher Professional Development (research brief). Effective Teacher Professional Development (Research Brief), (June), 1–8.

Davis, E. A., & Krajcik, J. S. (2005). Designing Educative Curriculum Materials to Promote Teacher Learning. Educational Researcher, 34(3), 3–14. https://doi.org/10.3102/0013189X034003003

DESE (2020). Guide To The Missouri Assessment Program 2020-2021. https://dese.mo.gov/college-career-readiness/assessment

Diamond, J. B. (2021, July 20). Racial equity and research practice partnerships 2.0: A critical reflection. William T. Grant Foundation. Retrieved January 12,2023, from https://wtgrantfoundation.org/racial-equity-and-research-practice-partnerships-2-0-a- critical-reflection

Fishman, B., Penuel, W., Allen, A. R., Cheng, B., & Sabelli, N. (2013). Design-based implementation research: An emerging model for transforming the relationship of research and practice. Teachers College Record, 115(14), 136-156.

Gallagher, H. A., Arshan, N., & Woodworth, K. (2017). Impact of the National Writing Project's College-Ready Writers Program in High-Need Rural Districts. Journal of Research on Educational Effectiveness, 10(3), 570–595. https://doi.org/10.1080/19345747.2017.1300361

Grossman, P., & Thompson, C. (2008). Learning from curriculum materials: Scaffolds for new teachers? *Teaching and Teacher Education*, 24(8), 2014–2026. https://doi.org/10.1016/j.tate.2008.05.002

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Promoting Conceptual Change in Science: A Comparative Meta-Analysis of Instructional Interventions from Reading Education and Science Education. *Reading Research Quarterly*, 28(2), 116. https://doi.org/10.2307/747886

Hattie, J. (2008). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement (pp. 1–378). Routledge Taylor & Francis Group. https://doi.org/10.4324/9780203887332

Hayes, K. N., Lee, C. S., DiStefano, R., O'Connor, D., & Seitz, J. C. (2016). Measuring Science Instructional Practice: A Survey Tool for the Age of NGSS. Journal of Science Teacher Education, 27(2), 137–164. https://doi.org/10.1007/s10972-016-9448-5

Hayes, K., & Trexler, C. (2016) Testing Predictors of Instructional Practice in Elementary Science Education: The Significant Role of Accountability. Science Education, 100(2), 266-289

Jackson, J. K., & Ash, G. (2012). Science Achievement for All: Improving Science Performance and Closing Achievement Gaps. *Journal of Science Teacher Education*, 23(7), 723–744. https://doi.org/10.1007/s10972-011-9238-z

Landry, S. H., Anthony, J. L., Swank, P. R., & Monseque-Bailey, P. (2009). Effectiveness of comprehensive professional development for teachers of at-risk preschoolers. Journal of Educational Psychology, 101(2), 448–465. https://doi.org/10.1037/a0013842

National Science Teaching Association. (n.d.). NGSS@NSTA. About the Next Generation Science Standards. Retrieved July 27th, 2023, from https://ngss.nsta.org/About.aspx

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. In Educational Research Review (Vol. 14, pp. 47–61). Elsevier Ltd. https://doi.org/10.1016/j.edurev.2015.02.003

Penuel, W.R. (2019). Infrastructuring as a Practice of Design-Based Research for Supporting and Studying Equitable Implementation and Sustainability of Innovations, Journal of the Learning Sciences, 28:4-5, 659-677, DOI: 10.1080/10508406.2018.1552151

Penuel, W., & Gallagher, D. (2017). Creating research-practice partnerships in education.

Cambridge: Harvard Education Press.

Piaget, J., & Cook, Margaret. (1952). The origins of intelligence in children. New York: International Universities Press.

Powell-Moman, A. D., & Brown-Schild, V. B. (2011). The influence of a two-year professional development institute on teacher self-efficacy and use of inquiry-based instruction. Science Educator, 20(2), 47–54.

Roblin, N. P., Schunn, C., & McKenney, S. (2018). What are critical features of science curriculum materials that impact student and teacher outcomes? Science Education, 102(2), 260–282. https://doi.org/10.1002/sce.21328

Ruggirello, R., & Brockhouse, A. (2023). Equitable from the Start: Strategies for making science relevant, engaging and accessible. Science and Children. In press.

Ruggirello, R., Brockhouse, A., & Elkana, M. (2023). Leveraging strengths of a research-practice partnership to support equitable science teaching during the COVID-19 pandemic. Cultural Studies of Science Education. In press.

Smith, P. S., Trygstad, P. J., & Banilower, E. R. (2016). Widening the gap: Unequal distribution of resources for K–12 science instruction. Education Policy Analysis Archives, 24(8). http://dx.doi.org/10.14507/epaa.24.2207

Taylor, J. A., Getty, S. R., Kowalski, S. M., Wilson, C. D., Carlson, J., & Van Scotter, P. (2015). An Efficacy Trial of Research-Based Curriculum Materials With Curriculum-Based Professional Development. *American Educational Research Journal*, 52(5), 984–1017. https://doi.org/10.3102/0002831215585962

Tinnin, R. K. (2000). The effectiveness of a long-term professional development program on teachers' self-efficacy, attitudes, skills, and knowledge using a thematic learning approach (Order No. 9992926). Available from ProQuest Dissertations & Theses Global. (304639123). Retrieved from http://libproxy.wustl.edu/login?url=https://www-proquest-com.libproxy.wustl.edu/dissertations-theses/effectiveness-long-term-professional-development/docview/304639123/se-2?accountid=15159

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2015 Science Assessment. Retrieved from https://www.nationsreportcard.gov/ndecore/xplore/nde.

Yoo, J. H. (2016). The effect of professional development on teacher efficacy and teachers' self-analysis of their efficacy change. Journal of Teacher Education for Sustainability. De Gruyter Open Ltd. https://doi.org/10.1515/jtes-2016-0007

Vygotsky, L., & Cole, Michael. (1978). Mind in society : The development of higher psychological processes. Cambridge: Harvard University Press.

Young, B. J., & Lee, S. K. (2005). The effects of a kit-based science curriculum and intensive science professional development on elementary student science achievement. *Journal of Science Education and Technology*, 14(5–6), 471–481. https://doi.org/10.1007/s10956-005-0222-2

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