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The Peer-Enabled Restructured Classroom (PERC): Harnessing the Power of Urban Students to Achieve Success in STEM Classrooms

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Abstract

The Peer-Enabled Restructured Classroom (PERC) is an educational model for secondary school science and mathematics classrooms that was developed in New York City public schools under the auspices of a National Science Foundation-funded Math Science Partnership (MSP) between the City University of New York (CUNY) and the New York City Department of Education (NYC DOE). PERC successes demonstrate that middle-performing students in urban, often low-performing schools can be an integral resource to support academic reform and the success of all students. The origins, development, and implementation of PERC in multiple New York City public schools are reviewed in this retrospective. Research studies on the effects of PERC on the students, near-peer leaders, and teachers in the classrooms are presented. PERC demonstrates that restructuring classrooms to engage students deeply in peer instruction can empower students, including those from low-income, often under-resourced school communities, to become student leaders and achievers.

Keywords: Peer Instruction, Collaborative Learning, Teacher Development, School Change, Secondary Education, Urban Schools

Introduction

The Peer-Enabled Restructured Classroom is an educational model developed from 2010 to 2018 under the auspices of a Math Science Partnership funded by the National Science Foundation (NSF). A broad collaboration between faculty from the City University of New York (CUNY) and the New York City Department of Education (NYC DOE) secondary schools, the primary goal was to improve student success in science and mathematics courses in high school, enhance high school graduation rates, and facilitate acceptance to CUNY senior colleges. This goal was to be effected through collaborations among disciplinary college faculty in the domains of science, technology, engineering and mathematics (STEM), teacher educators, and secondary school teachers and administrators. The project was conceived on the principle that building partnerships based upon mutual respect would enhance fundamental understanding of the challenges that face instruction. This would then result in new strategies to improve the success of low-income minority students in New York City public schools. The instructional model developed under this major project was called the Peer-Enabled Restructured Classroom (PERC) because of its most visible feature: high school STEM classrooms entirely reorganized around near-peer group learning leadership, that is, small-group instruction led by grade-adjacent peers.

An era of national educational reform

The PERC model grew in the wake of an era of national reform at the collegiate and secondary school levels to improve STEM education. The 1990s was a decade of national science reform stimulated in large part by the publication of *A Nation at Risk* (National Commission on Excellence in Education, 1983). The NSF responded to the clarion call for changes in education broadly, and STEM education specifically, with funding to support large-scale, highly collaborative, research-based curricular and pedagogical changes in K-12 and college classrooms. The NSF recognized that the key to maintaining the United States' leadership in STEM was broadening the participation of all Americans in the sciences. The student populations at CUNY colleges are racially and ethnically diverse and are primarily New York City students from low-income backgrounds. At the time that PERC came into being, student success in CUNY undergraduate STEM classrooms, as defined by passing rates, were often low, and instruction was primarily in large lectures with small labs. As part of its commitment to providing a public first-rate education to all students, regardless of means or background, CUNY supported change in the way its colleges approached undergraduate STEM education.

At the same time, evidence was building about the successes of Supplemental Instruction involving peer-assisted learning (Martin & Arendale, 1992) and the effectiveness of student-to-student collaborative learning (e.g., Johnson & Johnson, 1990). By the end of the 20th century, it was documented that "active learning" and collaborative approaches to pedagogy in college classrooms would dramatically increase student success, thereby broadening access to STEM careers for students from groups underrepresented in science. In 1995, City College of New York, CUNY, led one of the five national NSF collaborative awards to develop the "Workshop Chemistry Curriculum," a collaborative learning, peer-led approach to chemistry instruction. CUNY's version of Peer-led Team Learning (PLTL), a well-documented model for student success across multiple disciplines (Wilson & Varma-Nelson, 2016), emerged from that project. In 1996, Hunter College, CUNY, received both NSF and funding from the U.S. Department of Education to develop an integrated chemistry, physics and mathematics introductory set of courses based on a collaborative model of instruction. Student success in the introductory classes rose significantly, consistent with other documented successes in physics and mathematics.

The context of New York City public schools

While the above initiatives began to improve CUNY's undergraduate programs in STEM, the reasons that many low-income and minority students struggle to succeed in STEM also strongly relate to their educational opportunities before college. It is helpful therefore to understand the context of secondary education in NYC in the late 1990s and early 21st century. NYC was one – and remains one – of the most racially segregated systems in the country (Bonastia, 2022). Major reforms of the 1990s such as the charter school movements did not address the racial segregation and resource limitations of the public schools that most NYC children attend. Under the No Child Left Behind Act of 2001, schools that failed to show growth in student outcome metrics closed or became at risk for closure or reorganization. In this milieu, many small new schools opened with specific missions that included increasing graduation rates. Many existing, low-performing schools that served high numbers of minority and low-income students sought partners to improve their success.

Success in secondary schools in the state of New York (NYS) tends to be defined by student performance on end-of-course standardized exams (Regents), which have been administered to high school students since 1866. Historically, Regents exams were not required for graduation and were a mark of prestige; students could complete high school without passing Regents exams, although basic competency exams were required beginning in 1981 to achieve a local diploma. Beginning in 1995, NYS phased out the local diploma system, and all students were required to pass a set of Regents exams. By 2001, a New York state diploma required passing five Regents exams by earning a scaled score of 65 or higher. The required five tests included, at that time, two tests in STEM domains (one math, usually algebra, and one science exam, usually biology). Additional STEM Regents exams in geometry, higher-level mathematics, chemistry, physics, and earth science were optional;

high scores on those exams allowed students to demonstrate more advanced academic proficiency, earn an Advanced diploma, and helped students enter four-year colleges.

The roots of PERC: The Hunter College Summer Chemistry Academy

The Hunter College Summer Chemistry Academy, funded by CUNY in 2002, combined work at Hunter College to re-invigorate science teacher education programs with college outreach to the NYC DOE high schools and their students. This summer program had the explicit, immediate goal of improving passing rates in chemistry on the end-of-summer administration of the Regents exam and then translating successful summer practices into high school. Students who had completed the chemistry course but had failed the end-of-year Regents exam could attend the Summer Chemistry Academy on the Hunter College campus in lieu of a typical summer school course resident at a high school. Two high school chemistry teachers and two college faculty members co-taught the students. The high school teachers were not only driven to help students show proficiency at summer's end; they also aspired to raise their own academic year passing rates on the Chemistry Regents exams to 100% in the non-selective high schools where they worked. This was an ambitious goal, given that typical chemistry passing rates in New York City schools were under 30%, and a goal reflective of their belief that all students can learn.

The curriculum for the Summer Chemistry Academy focused on the content required for the chemistry Regents exams. School ran on the Hunter College campus all day for five days a week from July 1 until the summer Regents exam, typically mid-August. It mimicked the timeframe of a typical NYC summer school with morning classes, five days a week, but with an innovative afternoon schedule. In the afternoons, undergraduates enrolled in chemistry and chemistry education programs led workshops with students for two hours, while the teaching faculty met for planning. At the end of the day, students, tutors, and faculty met together in their classes for daily wrap-ups and debriefs. Every week, students took a retired version of a chemistry Regents exam to give them practice and track their own improvement, and to give tutors and the instructional staff information to guide future teaching.

The two high school teachers recruited 25 students for the first Summer Chemistry Academy in July of 2002. The students came from the teachers' academic-year classes and had all failed their chemistry Regents exam just one month before. Though they reported skepticism about their ability to succeed in chemistry, all students stuck with the summer program, and took the August exam at a NYC DOE designated testing center. The two licensed high school teachers participated in the citywide grading but did not grade the exams of any of the students enrolled in Summer Chemistry Academy. To everyone's delight, all 25 students passed the exam – an outstanding 100% passing rate, especially in comparison to the citywide passing rate of the summer exam of not quite 6%. Clearly something had worked.

To try to replicate the first Summer Chemistry Academy, CUNY funded another summer institute the following year, and the instructional staff expanded with a third teacher from another non-selective high school. Again, more than 20 students who failed the exam in June attended. That year, some tutors were recruited from the high schools as well as from the Hunter program in chemistry education. Again, all students passed the exam in August. The summer school became a laboratory that enhanced the skills of the student teachers as well as the high school and college faculty, and it laid the foundation for the first NSF-funded Math Science partnership: MSPinNYC.

A foundational experience: MSPinNYC

In the summer of 2003, the CUNY Dean of Teacher Education, Nick Michelli, in partnership with the NYC DOE Science Leader, Linda Curtis-Bey, decided to submit an NSF Math-Science-Partnership proposal to enhance secondary student success across both the high school and CUNY college STEM classes. CUNY called for suggestions and ideas, and faculty across CUNY submitted white papers for potential inclusion in the proposal. Michelli and Curtis-Bey made the decision to apply for the MSP grant based in significant part on the chemistry summer school. Hunter College was selected to be the lead institution, with multiple CUNY colleges participating. The NYC DOE would select the high schools to participate in the partnership. The MSPinNYC proposal was funded by the National Science Foundation in 2004 as a Math and Science Partnership Program, with Hunter College and the NYC DOE as principal partners, and Pamela Mills as Principal Investigator.

The MSPinNYC used a "micro-macro" model to effect change. The micro approach was a novel model for professional development of faculty from the secondary schools and colleges, with the summer school as their core laboratory for learning and practice in a collaborative teaching enterprise. In this summer school laboratory, in addition to working with high school students, time was allocated daily for the collaborating teams to meet and discuss classroom successes and failures. Time was also allocated during the academic year for all participating faculty to engage in discussions regarding best ways to infuse summer practices into the regular academic day. Researchers and evaluators studied MSPinNYC practices and progress towards the goal of student learning impacts as measured by Regents exam outcomes. The MSPinNYC worked with teachers and students in multiple STEM domains, including biology, chemistry, physics, algebra, and geometry, all of which culminated in Regents exams. Participating classes at the college level included introductory courses in pre-calculus, chemistry, and physics.

The "macro" strategy focused on institutional change, which relied upon dissemination of effective practices emerging from the classroom experiences. The MSPinNYC leadership offered formal and informal opportunities for school, district, and college leaders to meet with the core partners, researchers, and evaluators for discussions of wider implementation across the systems. New data agreements between NYC DOE and CUNY enabled access to data to conduct quasi-experiments and assess quantitative outcomes.

The micro-macro model implementation produced considerable opportunities for faculty across the DOE and CUNY to interact and learn the successes and challenges from each other. The professional development summer model that utilized both college and secondary school faculty in the classroom helped college faculty gain greater insights into the high school challenges and the content expectations. Summer schools were robust and summer outcomes on Regents exams continued to be dramatically higher than traditional summer school outcomes. Like the original chemistry summer school, the MSPinNYC summer schools were full-day courses requiring students to focus on one course in the summer. Summer courses were offered that covered New York State standards in algebra, geometry, biology, and chemistry. In each course, the majority of students passed the Regents exams, exceeding city averages by factors of 2 to 4.

Despite the continuing and ongoing success of the summer schools, the translation to the school year produced limited improvements in Regents scores. It was clear that the summer schools proved that the students in the science classrooms had the ability to succeed given the summer environment. It was clear that faculty across schools and systems could collaborate, and that data sharing was producing the possibility to unravel some of the confounding variables. It was clear – from reports of the summer school students themselves – that the major resources that helped students succeed were their "tutors," and the culture of respect and expectations in the summer. The MSPinNYC leadership team pondered the translation of these key factors: tutors, collaboration, and respect. Translating the tutor experiences to the high school classrooms appeared to be both economically and practically impossible, given the assumption that only high-performing upper grade students or undergraduates could be tutors. Further, principals told the team that they were unwilling to make their honors students available to be tutors in the program because these students were essential to a different mission in the schools.

The summer classes dating from 2002 had routinely employed tutors at the undergraduate level. However, there were also a few tutors from the high schools themselves – students who had passed the Regents exams in June, but with mediocre scores. The MSPinNYC leadership team noted that those "middle performing" students were often outstanding tutors. They could convey classroom expectations to the students, and they could help students pinpoint difficult pitfalls. Conversations between tutors and faculty were often rich with insights and ideas. The MSPinNYC leadership realized that there were numerous such students in urban high schools – middle-performing students who are often overlooked, as they appeared to be neither leaders nor in critical need of support. The MSPinNYC team asked if schools could harness the potential of cohorts of middle-performing students, if classrooms could be restructured to be more collaborative, and if the tutors could become teaching assistants in the classrooms every day. In other words, could the factors identified by the summer students be replicated in academic year classrooms? And at minimal cost? The Peer Enabled Restructured Classroom (PERC) model was developed at the end of the first, 2004 MSPinNYC grant with positive and intriguing results. These results were used to propose the MSPinNYC2 project that was funded to implement and evaluate PERC.

The model: MSPinNYC2 and PERC

Perhaps the crucial moment in the timeline of development and implementation for the PERC model (see Figure 1) occurred in 2011, when the National Science Foundation funded the MSPinNYC2, "MSPinNYC2 – A New Partnership to Transform Urban Secondary School Mathematics and Science Experiences," with Pamela Mills as Principal Investigator. A robust team, composed of college and high school faculty in math and the sciences, science education; school administrators; researchers, evaluators, and data analysts; and partners at the NYC DOE, made PERC happen. Everyone contributed. Teachers learned to turn most of their daily activities in 9^{th} grade STEM classes over to the Peer Leaders. The peer-leaders, called Teaching Assistant Scholars or TAS, pushed themselves for content mastery and teaching skill. School administrators scheduled separate credit-bearing classes for TAS learning and practice. Teacher educators used coaching and the summers as intensive professional development laboratories to build trust and deep relationships that inspired teacher change. Researchers, evaluators, and data analysts from different institutions engaged in common inquiry and assessment of the program. The NYC DOE helped the team identify high schools whose missions and needs aligned with the vision of PERC.

Operationally, a PERC math or science class began with an opening task completed in TAS-led groups to activate and assess prior knowledge. The teacher then transitioned to a brief mini-lesson of perhaps 10 minutes that provided a conceptual context, punctuated by discussion questions for the groups. Then, the students engaged in solving problems, practice, and rehearsal of learning in small instructional groups led by their near-peers, the TAS. TAS were students of similar ability but one grade advanced in content relative to the student learners – students "in the middle," who had passed the course and associated state Regents exam at a level of only minimal proficiency at the end of the prior year. Students spent most of class time in group work facilitated by the TAS, who asked questions, extended critical thinking, offered encouragement, and formatively assessed performance. The typical ratio of TAS to student learners within a classroom was 1:5. TAS received content reinforcement and training in small-group pedagogy through their peer learning leadership class, informally called TAS class.

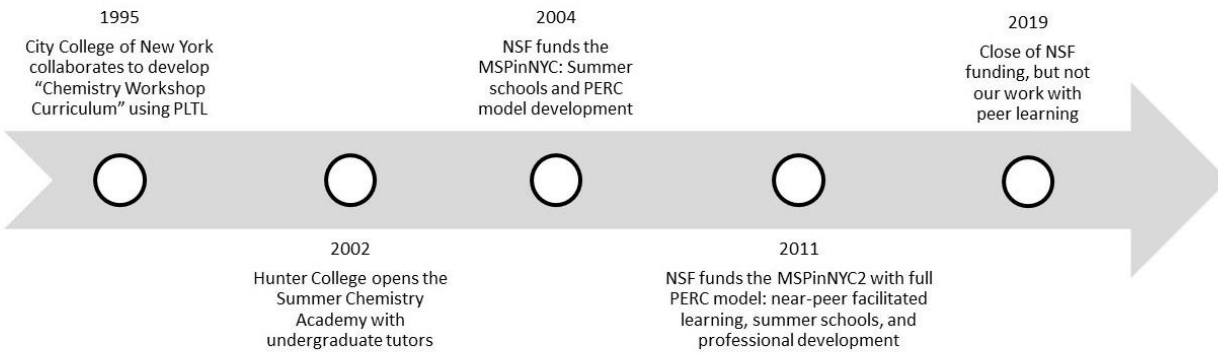

Figure 1. Timeline for PERC Development and Full Implementation

In addition to their practical experience leading small group instruction in a STEM class, TAS enrolled in the TAS class that met daily and had its own curriculum. The curriculum for the course was created to elaborate content learning, develop metacognitive skills, build student positive self-perceptions, and raise college awareness. Lessons covered topics such as self- and peer-explanation, questioning, prior knowledge analysis, motivation, time management, college financial aid, and transcript review. Creating schedules that allowed TAS to take this specialized course, as well as engage in peer facilitation daily, posed one of the most significant challenges for schools interested in implementing PERC. It required administrators, counselors, and teachers to think creatively and use data-driven decision-making to craft four-year plans for the TAS that would maximize their preparation for college.

In NYS, students were required to complete 44 semester courses to graduate, but many participating schools had eight periods in their day, meaning that students could accumulate 64 semester credits over their four years. Because they did not need up to 20 credits, many seniors were enrolled in very few courses and had multiple free periods. School administrators were often reluctant to count on those available periods because they expected students to need to retake classes that they had failed the first time.

The PERC team proposed another way of thinking: if administrators invested time at the beginning of students' high school careers to support long-term academic success, they would find less need for cushion periods to accommodate retaking failed classes. With their mindsets focused on promoting success rather than reacting to failure, PERC school administrators were persuaded to schedule two periods a day for students who acted as TAS – one for the STEM class in which they acted as Peer Leaders, and one for the TAS class. Some schools used the STEM peer-leadership class to fulfill a school leadership requirement; others awarded internship credit for being a Peer Leader. Most schools assigned elective mathematics or science credit for the TAS class.

Another logistical concern for administrators was an apparent "gap year" in mathematics or science. Spending a TAS year also meant delaying geometry or an advanced science course for a year. Delaying a geometry course, in particular, could mean that students would not take precalculus before graduating from high school. However, upon reviewing data closely, administrators saw that many middle-performing students like the TAS, who had not yet reached the state "college-ready" benchmark score in algebra, were not in fact ready to move on to geometry, as evidenced by high failure rates of those students on the Regents geometry exam. PERC data showed that spending a year as a TAS dramatically increased likelihood of their reaching the state college-ready benchmark score in algebra. The PERC program argued that it was wiser to delay geometry, than to allow students to take the course with the probability of failing the exam. The PERC Program addressed the delay in completing the math sequence by offering a summer class in geometry for the TAS. The PERC team created similar accommodations for the science sequence.

The core of teacher professional development for the MSPinNYC2 was the summer school and summer teacher institute, maintaining continuity with the original Summer Chemistry Academy. New PERC teachers learned to implement PERC and work with TAS during a five-week summer school before their first academic year in the program. Summer school classes were team-taught by novice PERC teachers mentored by experienced PERC teachers, PD staff, CUNY faculty, and the TAS themselves (Keiler et al., 2019; Keiler et al., 2020a; Keiler et al., 2020b), using the peer-led pedagogical model with experienced TAS. All classes used the pedagogies of the relevant academic year course. Math and Science teachers learned how to develop and implement lessons facilitated by TAS, growing into their new roles in the classroom. Both in-the-moment feedback during lessons and afternoon daily summer feedback sessions with TAS and with PD staff supported reflection and professional growth in planning and implementing PERC classes (Keiler et al., 2020; Keiler et al., 2020b). Analysis of weekly practice exams results developed teachers' skills and habits for data-driven decision-making during the academic year. The summer school and teacher professional immersion experience were directly modeled after the successful MSPinNYC summer schools, in turn modeled on the Summer Chemistry Academy.

All teachers also received extensive academic year coaching and mentoring. Teachers argue that mentoring must focus on their daily work and the realities of their classrooms (Carter & Keiler, 2009). The MSPinNYC2 mentoring program focused directly on the challenges that teachers faced in implementing PERC and supporting TAS to be Peer Leaders. During the academic year, the PD staff built upon mentoring relationships established in the summer immersion through weekly observations and meetings. The PERC teachers participated in monthly, program-wide PD days that supported the development of a PERC teacher community, and TAS participated with their teachers in these all-day sessions once per semester. Teaching the TAS class also served as a professional development experience for PERC teachers. In order to teach the TAS class, the PERC teachers had to think deeply about and teach pedagogy. They also received feedback from their TAS about the effectiveness of their teaching. These combined PD experiences supported the PERC teachers over their first two years in the program, at which point they started providing PD support for their PERC peers.

Research on students

Because Regents exam performance is crucial to student high school graduation and college acceptance, and poor performance on Regents can lead to whole-school reorganization, evaluation of the success of the PERC model in the eyes of the NYC public school system relied on it having positive effects on the Regents scores of 9th grade students who took PERC STEM courses, and the TAS who supported their learning. To gather evidence about PERC effects, the MSPinNYC2 leadership team did research on PERC in six schools, all of which showed a dramatic need for interventions targeting this student population, with high numbers of students failing exams in basic algebra and science. A typical student in one of these schools was likely to enter community college in need of remediation (Logue, 2011). If PERC could help those typical students – the "students in the middle" – catch up to college readiness, the entire trajectory of their education might change.

The theory of learning that predicts PERC impacts on student achievement is essentially social-cognitive constructivism (Vygotsky, 1978). A program like PERC – and other collaborative learning and teaching models such as Peer-Led Team Learning – raises student achievement because learners and leaders engage in cognitive partnership. Topping (2001, 2005) synthesized a model to describe why this partnership works particularly well in near-peer learning environments. Topping's (2001) theoretical work depicts a five-level model of processes that support learning in peer-assisted environments. Although PERC involved all levels, the emphasis was on Levels 1 and 4: engagement, interactivity, error management; and feedback and reinforcement. It would be clear to any observer of a PERC classroom that 9th graders were intensively engaged. As they worked in their near-peer led learning groups, they were busy solving problems, engaging in self- and peer-assessment, and explaining their thinking. The quantity and immediacy of feedback they received was many times greater than a single teacher could give in a class of 30 students. Theoretically, and based on prior research (e.g., Bisra et al., 2018; Double et al., 2020; Hattie & Timperley, 2007), the PERC research team expected that the program would cause improved achievement among 9th graders in PERC math and science.

PERC impacts on 9th Graders in algebra and biology

The team submitted its hypothesis to a rigorous quasi-experimental test, predicting that students who learned in small groups with near-peer TAS would have higher academic performance than comparable students who did not experience such activities (Thomas et al., 2016). The 9th graders in this study had all been continuously enrolled in a full-year class with multiple TAS (more than three) present daily; whose Peer Leaders were simultaneously enrolled in the TAS class; and who took the algebra or biology Regents exam at the culmination of their course.

For a comparison group, a team of researchers and data analysts gathered data from a large pool of NYC students enrolled in schools who were considered “peers” of the PERC schools. Peer schools are NYC public schools with a student population most like the population in the PERC school, based on a peer index which is calculated at the city level (NYC DOE, 2015a). Under a data-sharing agreement with the NYC DOE, the CUNY Office of Research, Evaluation and Program Support provided data on non-PERC students in these schools, including demographics, state-sponsored achievement test scores, course participation, and so on. The research team used the NYC DOE data and the method of propensity score matching to derive a pseudo control group composed of NYC students that closely resembled the students in PERC. This quasi-experimental method facilitated estimation of the causal effects of PERC on student achievement over the first two years of implementation.

Results of the team’s analyses showed that taking a peer-led course in high school biology positively affected the likelihood of passing the New York State Regents exam. Students in a peer-led biology course were 1.46 times more likely to pass the test and scored on average three points higher on the course Regents exam than if they had not been in a peer-led course. This was an improvement in PERC impacts over the first year of implementation, when there were no significant differences. PERC impacts improved between the 1st and 2nd year of program implementation in algebra, both in terms of scale score on the Regents examination and in terms of passing rates. However, neither the improvement nor the overall impact of PERC was statistically significant in algebra.

Partly explaining the mixed results, the team understood that the peer schools it drew on for comparison were almost definitionally in the same need of academically supporting programs and were responding with new kinds of curriculum and resources. Thus, the test was not one of PERC versus “business as usual” at the peer schools, but more likely PERC versus other innovations. Further, the data that were analyzed came from the early years of program implementation, before PERC had time to become well-established in its schools. A ubiquitous problem in educational reform is that innovative programs that initially show only lackluster outcomes are sometimes judged – and forgotten – based solely on those early results. It was important to study the PERC model’s effects over time and on other program participants, particularly the TAS and their teachers.

<u>TAS and how they grew</u>

Thus, concurrent with its research on the academic achievement of the 9th graders in the PERC classrooms, the PERC team studied the psychological and social-emotional aspects of the TAS Peer Leader experience. After all, while effects on the population of mostly 9th grade students in early STEM courses was desirable as strong evidence of the PERC effect, the "students in the middle" – TAS Peer Leaders – were the heart of the MSPinNYC2 program. The team's belief in TAS change was based on observation of individual students, as well as large body of research indicating that instructional leadership positively affects non-cognitive factors for peer or near-Peer Leaders, such as self-perceptions, behaviors, motivation to learn, and social and emotional skills (Cohen et al., 1982; Miller et al., 2010; Robinson et al., 2005).

PERC researchers studied three dimensions of TAS growth: academic achievement, self-regulated learning (SRL), and perceptions about leadership roles (Bonner et al., 2017). SRL was a focus because, according to Topping's model of peer-instruction, TAS – like any other peer academic leaders – were theoretically expected to develop academic self-regulatory skills through teaching others. In their review of SRL strategies, Kistner and colleagues (2010) defined cognitive organization, planning, resource management, monitoring and evaluation as activities that develop SRL. The TAS Class curriculum included lessons on SRL strategies such as using resources, time management, use of study teams, and setting, monitoring, and reflecting on academic goals. The study also focused on leadership perceptions as falling under the broad umbrella of role theory, which is often invoked to explain social-emotional benefits of near-peer instructional leadership. Role theory has been used, for instance, to explain the phenomenon detected in Leung's (2014) meta-analysis that low-achieving students benefit most from being academic Peer Leaders. Under role enactment theory, learners who act as leaders may perceive themselves enacting new roles through the evolution of their interactions with learners (Lynch, 2007; Sarbin & Allen, 1968), promoting motivation and creating learning gains.

First, to assess TAS learning gains, PERC researchers used Regents exams taken from the end of the school year before they became TAS, which were at or near the eligibility benchmark of 65. At the end of their year of instructional leadership, TAS re-took the examination in their content area, in order to achieve a higher score on their diploma. This post-test Regents score measured achievement in the content area after the TAS experience. TAS took a survey in the fall term near the start of the school year, and again in late spring of the same academic year. The survey included five subscales of the Motivated Strategies for Learning Questionnaire (MSLQ): Peer Learning, Organization, Critical Thinking, General Strategies for Learning, and Clarification Strategies for Learning (Dunn et al., 2012; Pintrich et al., 1993). It also included an adapted version of the Mentor Survey (Pre and Post) (AWE, 2010; Micari et al., 2010). The Mentor Survey measures self-reported abilities to engage in small group facilitation, such as motivating, explaining concepts, managing groups, and helping without giving answers.

As expected, TAS scored significantly higher on the Regents examination in their content area at the end of the year than they had the prior year. Effect sizes for change in proficiency in the content areas were large for both algebra and biology groups, ranging from one-half to two-thirds standard deviation growth.

Based on regression analyses that controlled for their prior test scores, TAS in algebra, initial perception of mentoring skills and development of organizational learning strategies were significant predictors of growth in achievement. In other words, the algebra TAS who most profited academically from PERC were those who entered with the strongest perceptions of themselves as leaders. Then, over the course of their year in the program, those who developed skills in organizing their own learning – outlining, using notes, making visual aids – experienced significant boosts in achievement.

In biology, development of critical thinking strategies was a significant predictor of learning gains. Critical thinking was operationalized using items about self-questioning and seeking evidence for conclusions. Among biology TAS, after controlling for prior achievement and other variables, those who developed skills in questioning and thinking critically about information showed the strongest achievement gains.

Academic impacts on TAS: College readiness

Because of the severe need to help students move into college course-taking without need for remediation, members of the PERC research team designed a third study (Bonner & Thomas, 2017) to answer this question: did TAS progress towards entering college readiness more than would be expected if they had not been TAS? We examined outcomes for TAS in math due to the availability of large data samples. Data from three samples of math TAS ranging in size from 128 to 178 were analyzed. For each sample, there were majorities in the following categories: female, Latino and/or Black, English spoken as their native language, and failure to reach proficiency in English Language Arts in 8th grade. About half of each TAS sample had reached proficiency in Math on their 8th grade state test.

Samples of student data from a large pool of 10th grade NYC students from either of those academic years in a school with similar characteristics as indicated by the NYC DOE peer index (NYC DOE, 2016) made up the comparison groups, as in the earlier study of 9th grader outcomes (Thomas et al., 2016). The samples ranged in size from 9,923 to 13,808 students from approximately 280 schools, depending on the outcome analyzed. Covariates included the year of 10th grade, gender, race/ethnicity, native language, 8th grade English Language Arts scale score, and 8th grade Math scale score to generate a matched sample with good balance.

Outcomes at each stage were based on the CUNY requirements for enrolling in CUNY without need for remediation in math. CUNY benchmarks are an important metric as nearly 60% of NYC DOE students who go on to college attend a CUNY institution (NYC DOE and CUNY, 2016), and CUNY attendance consists primarily of students (74%) who attended NYC DOE schools. The nearest-term benchmark was operationalized as passing New York State mandated mathematics examinations by the end of 10th grade at a level recommended by CUNY. Using the state test score, the researchers also created a binary indicator of whether students reached the Regents score required for entering CUNY without needing remediation (80 or above) by the end of the academic year following the end of 10th grade – and indicator of “on track” academic progress.

The midterm benchmark was meeting New York City minimum standards for entrance to 4-year colleges in CUNY by the end of 11th grade. Students who fail to meet this benchmark would either exert essentially self-remediation to meet it in their senior year of high school, or plan to attend a community college. This outcome was measured based on the highest Regents mathematics test score achieved by 11th grade, including over multiple attempts, converted to a binary indicator of whether or not students met a local CUNY benchmark in mathematics by the end of 11th grade.

The longest-term benchmark was entering a CUNY postsecondary school without need for remediation in math. For this outcome, student achievement data from a time point two years after the instructional leadership experience were used to create a binary indicator based on a combination of all academic criteria for exemption from remediation according to CUNY: Regent’s mathematics scores, SAT math score, or the CUNY math placement examination.

Based on linear and logistic regression analyses, performance on the near-term outcome, or state algebra test scores at the end of 10th grade, showed that TAS in algebra scored approximately 11 points higher on average on the state exam than their matched peers. Their likelihood of scoring at the mastery level on the Regents exam was eight times that of their matched peers. In the intermediate term, TAS’ likelihood of meeting the college-ready CUNY benchmark by the end of 11th grade was 3.8 times greater than that of their peers. For the longest-term prediction – entering CUNY without need of remediation – the TAS were 1.7 times more likely to meet the math benchmark than if they had not been TAS. What lessons were learned from this research on students in PERC? First and foremost, acting as near-peer instructional leaders had tremendous effects on near-term performance, and those effects endured all the way into college entry. TAS achievement gains were linked to growth in self-regulated learning over the course of their year as PERC leaders. In math, learning organizational strategies helped boost achievement, while in biology, critical thinking gains helped towards the same end. From this, we learned that TAS preparation for the different content domains of math and science should be more differentiated, not only in learning in the content areas, but in the learning strategies TAS practiced. Finally, the PERC research team took the mixed results of its study of 9th grade PERC student impact as a lesson in humility. However, the effects of PERC on students should not be judged only by impact on 9th graders' test scores – there was the psychological and academic development of more than a thousand TAS to celebrate. Further, we considered the effect of PERC on the classroom teachers who worked in the peer-led classrooms.

Lessons about teaching in a peer-led classroom

After multiple iterations involving much trial and error, the PERC Leadership and Professional Development Teams identified several "non-negotiables" that were essential for successful implementation. First, teachers had to participate completely voluntarily. Some teachers who were initially skeptical had epiphanies when observing the model in action and became effective adopters themselves. However, when principals put teachers in the program who were averse to it or who agreed solely to impress their administrations, the implementation failed. TAS reported that teachers who participated under duress only attempted to run a PERC lesson structure when the PD coaches were visiting. Otherwise, they reverted to their former practice of giving long lectures without any role for the TAS. While this occurred in a small minority of cases, the extreme difference in learning experiences for the TAS and students made it clear that teacher attitude was a driving force in successful implementation.

This connects to the second non-negotiable, which was that teachers had to believe that 1) all students can learn, and 2) students can learn from each other. Teachers who were dubious about either of these were unable to cede control of the learning experience to their TAS and students, limiting the fidelity of model implementation and its impact. The final non-negotiable was that the TAS class had to be a credit-bearing course for both teachers and students. When the TAS class met at a non-standard time such as lunch or after school and was essentially voluntary, neither the teachers nor the TAS prioritized the experience and the implementation of the model suffered.

Teachers and how they benefited

Teachers claimed that the most significant benefit they received from implementing the PERC model was learning deeply about their students. Much of this was a result of the change of role and primary activities of the teacher (Keiler, 2018; Keiler & Robbins, 2018). In the PERC classroom, teachers spent much more time listening than talking. They were leaders of instructional teams rather than being solely responsible for students' learning. In addition to their own in-class observations, discussions of students and their performance during TAS class enabled teachers to access important information about their students. The

TAS, working in small groups with students who were much like themselves, learned about specific skills and challenges faced by each student that were hidden from teachers who held positions of authority and worked at a larger scale.

PERC teachers also described the ways that the model itself and the deeper understanding of their students' needs enabled differentiation at a level never previously possible. Teachers shared that they were able to use their expertise as professional educators to reach students with specific needs, whether they were academically advanced or struggling for some reason. The model allowed them to spend extended time with these high-needs learners, which was not possible in classes where they had to focus on the general performance of the whole class. The teachers and TAS collaborated to assess students' progress and their needs as learners, creating differentiated learning experiences during TAS class based upon these assessments. Teachers then supported this differentiation during the PERC class, reaching many more individual learners than was possible on their own.

Teachers especially appreciated the ability of bilingual TAS to reach students with limited English proficiency. With a bilingual TAS in the group, the teachers could be sure that discussion in a language they did not speak was on topic and meeting the needs of the learners. The TAS translated between the teachers and students, facilitating this relationship and demonstrating the concern of the teachers. Teachers saw that the bilingual TAS were also able to support the transition of students for whom English was a new language, from speaking primarily their home languages to developing English proficiency, including scaffolding speaking in front of the whole class.

Another aspect of the PERC model that the teachers valued was the reduction in behavior problems they experienced in PERC classes. With a TAS at each table acting as a "localized educator," PERC students were neither bored nor frustrated. When they completed their work, the TAS provided the next challenge. When they were confused or lost, the TAS scaffolded the next steps in their task. Teachers and students noticed the dramatic difference in students' behavior in a PERC class compared to a class where the one teacher had to move from raised hand to raised hand. TAS also took it as a matter of pride when their groups were on task and thriving, leading them to redirect off-task behavior and share with their students the negative consequences they had experienced when they were not focused during class the previous year. Students saw the TAS as role models and followed their lead in being focused on learning rather than creating distractions.

<u>Challenges faced by teachers in a peer-led classroom</u>

The biggest challenge that the teachers faced was keeping themselves from talking during PERC class. One teacher shared that he had gone into education because he loved explaining his discipline, but he knew his students were not learning from that means of instruction. He saw the students thrive in PERC class when they had active control of their own learning process rather than being passive recipients of his expertise. He acknowledged that doing what he knew was best for his students was a struggle for him, and he realized that his professional fulfillment was now coming from mentoring his TAS. Even teachers who claimed that PERC enabled them to be the teachers they had always wanted to be, becoming facilitators of learning, had to learn to limit their mini-lecture time. Holding back on talking was also a challenge when teachers approached TAS groups who were mid-discussion. TAS reported that new PERC teachers frequently interrupted the flow of a meaningful exchange in their groups because the teachers did not know what had already been said or where the TAS was taking the discussion. TAS claimed to feel undermined and disrespected when this happened. Teachers had to learn to approach groups and listen to at least three exchanges before asking the TAS if they could make a comment or ask a question. The PERC PD Team developed note taking templates for the teachers to use to record their assessments of student learning and TAS performance to make sure teachers remembered that they had a specific and important role as they circulated among the groups. When PERC teachers employed these tools, they listened more carefully, interrupted less, and had important data for future decisions.

Connected to their reluctance to limit their talking was the fact that many PERC teachers initially faced challenges in trusting their TAS. The PERC model required them to relinquish much of the control of the learning to the TAS, who were not content experts. In fact, the TAS were students who had struggled in their classes the year before. However, the more responsibility teachers gave the TAS, the more impressed they were with these maturing adolescents. Ensuring that the TAS were prepared for their roles in PERC class was an essential component of the TAS class. The PERC teachers also had to learn to run TAS class as a collaborative learning environment and not revert to lecturing TAS about content so that they would be prepared to convey it to their students. Reminding teachers that the TAS needed to learn in the same ways as the PERC students was an on-going endeavor for the PERC PD Team. Teaching pedagogy to their TAS was a new experience for the teachers, who were used to teaching STEM. While teachers experienced some discomfort as they were growing into their roles as PERC teachers, those who willingly entered the program were universally positive about their ultimate experience and the impacts on their TAS and students.

Discussion and conclusion

The PERC program was unique in demonstrating the power of near-peer instruction in secondary school STEM settings where societal and institutional inequities produce under-resourced schools that struggle to achieve academic excellence. In such settings, teachers and students often lack the experiences of success that support belief in oneself and others.

Without success-experiences, either real or vicarious, students do not develop the kinds of motivation and self-efficacy that lead to long-term achievements (Bandura, 1977). There is a huge population of students in urban schools who pass their courses marginally, but rarely reach the highest levels of achievement – students in the middle. These students in the middle included the TAS who told us, when they achieved an 85 on the Regents exam that indicated mastery, that they didn't think such a score was real because they never knew anyone who had achieved it. PERC enabled expectations to change from "just passing" to "excelling."

PERC's successes derived from three central tenets: all students can succeed; middle-performing students represent an untapped resource for themselves, their peers, and society; and teachers can grow and excel professionally by handing over control and allowing students to co-construct learning. We have presented important lessons to guide other programs. For one, it is essential that students, Peer Leaders, teachers and institutions are all working to meet tangible goals. We operationalized success in terms of state-mandated test scores, which were required for school graduation, school accountability, and CUNY admission. Other programs might operationalize success in terms of passing key courses or completing the major. Not only do such goals motivate students, they help inspire teachers and school leaders to buy in to a model of peer-led teaching, as they witness the benefits of their students at first-hand level. At the same time, not all teachers and school leaders will agree to adopt a peer-led model with the same enthusiasm or success as PERC, and the model should not be foisted upon them. We learned to seek out teachers, often at the junior level, who had the capacity and drive for innovation. A third lesson learned was the centrality of respectful and collaborative partnerships among all stakeholders, whether they be teachers, principals and district leaders, or college faculty and administrators. Without strong partnership, even successful programs are often not sustained over time. Our experiences reveal the truth of the notion that one learns through teaching others. Moreover, when learners teach, teachers do more than disseminate knowledge; they help students learn with scaffolded and differentiated instruction. We made these truths evident by radically restructuring STEM classrooms, changing the daily lives of students and teachers. PERC shows that restructuring classrooms to deeply embed peer instruction among a large community of middle-performing students has the potential to transform teaching and can lead the often-overlooked middle into excellence.

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