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Using Science Concepts in a Mathematics Professional Development Program To Improve Student's Standardized Test Scores

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Abstract

Algebra I, formally described as a course covering expressions, functions, inequalities, systems of equations, exponents, real numbers and polynomials, has been known as a predictor of student success and college readiness. With this in mind, there is an urgent need to improve student performance in these courses. This paper describes a unique teacher professional development program that has the goal of increasing student success in mathematics using inquiry and team-based pedagogical strategies and integrating other STEM subject-area concepts into mathematics classrooms. In this article, we describe this regional, year-long professional development program composed of mathematics and science teacher pairs from the same campus. The program was designed to pair educators across content areas to discuss and implement best practices for teaching a curriculum aligning mathematics and science Texas Essential Knowledge and Skills (TEKS). The cohort of 79 8th and 9th grade mathematics and science teachers received over 100 hours of training throughout the year with the primary goals of providing resources and training, connecting mathematics and science classrooms, and providing teachers with team-building, mentoring and support. The educator cohort experienced both collaborative and inquiry-based, grade-level and content-specific professional development sessions. Teacher participants responded favorably to the program and that resulted in significant changes in teacher and student outcomes.

We evaluated the impact of the program on teachers through interviews, pre and post content tests, along with surveys. Several themes were apparent in the evaluation including an appreciation for learning how grade-level science themes can provide meaningful context for mathematics instruction and how peer-observation and mentoring opportunities are imperative for teachers of all levels of experience. Participating teachers had significant gains in both leadership assessments (total gain of 18.8%, $p<0.05$) and Algebra content post-tests (gain of 13%, $p<0.05$) using the Diagnostic Mathematics Assessments for Middle School Teachers (DTAMS). They also reported growth in readiness to teach core mathematics standards, teach mathematics to diverse student populations and implement inquiry-based mathematics techniques.

Student evaluation was primarily conducted through an analysis of student performance on state mathematics assessments. Employing the Texas Education Research Center (EdRC) database, which is a repository of Texas Education Agency (TEA) data, we have found that students of participating teachers had a significant increase in their performance on the Algebra I mandated state assessment test as compared to a well-matched group of comparison students. The mean score on the state Algebra I test for students of these teachers was 4065.3 (N=2456), in contrast to the mean scores of the comparison student group of 3954.7 (N=24,560). It is interesting to note that this correlates to participating teachers' students having an average score in the "Meets Expectations" category while the comparison group fell in the "Approaches Expectations" category as defined by the Texas Education Agency (TEA). This report will provide a practical groundwork for crafting cross-curricular professional development opportunities that lead to increased teacher self-efficacy and student achievement on standardized mathematics assessments.

Introduction

Mathematics courses have been described as a gatekeeper for student achievement for decades [1]. Although some contest that performance in these courses is merely an indicator of student success and not a contributing factor, many studies point to the pivotal role this subject plays in strengthening an important pathway toward academic progress for our students [2,3]. In a study published in 2012 from a large urban school district in the central part of the US, 87% of students who scored a D or better in their first algebra course graduated from high school, while 70% of students who failed the first Algebra I course they took dropped out [1]. Passing Algebra I is especially challenging for underrepresented minoritized students and contributes to lower levels of mathematics achievement [4]. Many studies also report that fewer minority students take algebra in 8th grade and that taking algebra in 9th grade or later hinders students' enrollment in advanced mathematics and science classes [3]. Students who struggle with mathematical competency are denied both essential skills and a particularly important pathway to economic and other opportunities, and often just quit school altogether.

Whether we are discussing grade-level promotion or graduation rates, students have always faced the "hurdle" of mathematics, particularly Algebra I, when working their way through secondary school. This need for mathematics success even reaches the university level where higher levels of achievement in these courses are shown to impact college admission, college retention and four-year graduation rates [5]. The critical nature of attaining mathematics knowledge and skills has led many educators and school districts to adopt creative ways to achieve this goal. One proven method of increasing student engagement and success suggested by the Common Core State Standards for Mathematics has been the teaching of mathematics in context [6]. A subject area that naturally has many close relationships to mathematics and can be used to provide this context is science. In fact, the National Council of Teachers of Mathematics [7] strongly recommends integrating and making connections between the subjects of mathematics and science.

One way of making pivotal correlations between mathematics and science is through teacher professional development (PD) programs. These programs are necessary, because in-service educators need to be proficient in the pedagogical knowledge of both mathematics and science to be effective at the integration of these subject areas [8]. Having in-service teachers participate in PD is essential as they are innovative and often able to try out big ideas in their classrooms [8]. PD programs are effective in aligning these two core subjects and increasing educators' skills at recognizing and exploring different connections between them [9]. This is made possible due to the fact that natural overlaps between the subjects exist that can potentially make the teaching of mathematics and science concepts indistinguishable from one another [10].

The individuals who stand to gain the most from these types of initiatives are the students who are able to be instructed by those who have had these PD opportunities. Interdisciplinary curriculum approaches give learners a chance to receive instruction that is both relevant and thought provoking [11]. There has also been a connection between integrated mathematics and science lessons and the larger concept of student motivation [12]. Additionally, students have the benefits of learning critical thinking skills and being able to reason logically by learning mathematics with real-world experimental data that can be provided by traditional science concepts [8]. One of the most noticeable outcomes and one most central to this study is the idea that pairing these two subjects has been shown to improve student attitudes and academic achievement [13].

In this study, we report the program structure and impact of a year-long PD program focused on improving the mathematics standardized test scores through giving participating teachers rich context to present content standards, mentoring opportunities, training in inquiry teaching methodologies and team-building over a sustained period of time.

Background

The goal of the Applied Mathematics Program (AMP!) is to develop and sustain a diverse Science, Technology, Engineering, and Mathematics (STEM) workforce that has the requisite scientific and technical skills needed to solve national challenges. AMP! does this by empowering STEM teachers with the knowledge and resources they need to engage and educate 8^{th} and 9^{th} grade students through a year-long teacher PD program. AMP! focuses on strengthening student reasoning skills and the connections between mathematics and science so that students are prepared for Algebra I as this course is known to be a gatekeeper for student progress and success in STEM [14,15]. In Texas, students typically take Algebra I in 9^{th} grade, therefore, AMP! is designed to provide PD for teachers in 8^{th} and 9^{th} grade. The data included in this report is from the 2017-2018 AMP! cohort of 79 teachers, with an analysis of how these teachers' leadership and content knowledge changed and how their students performed on the state mandated mathematics tests in the spring of 2018.

It cannot be overstated the importance of integrating mathematics and science in a meaningful and engaging way for students to be successful beyond the classroom. Unfortunately, for many educators access to PD that addresses the challenges of implementing integrated curriculum is insufficient. Several attributes needed to achieve quality teacher PD in STEM educational programs include the use of the engineering design process, promotion of inquiry, student collaboration, encouraging multiple viewpoints, having opportunities for formal and informal feedback, and time for teacher collaboration and the integration of math and science curriculum [16]. Most of the various PD available to educators do not address these issues, are often limited to a single day of training, do not have follow-up sessions, require teachers to miss instructional time, and/or can be too expensive for educators and their districts to take on. This study directly addresses these issues. AMP! is not a short-term workshop but rather a year-long teacher professional development program that provides teachers with 100 contact hours to acquire and apply new knowledge and reflect on their teaching practices. Several studies emphasize continuous PD that occurs periodically throughout the school year to best support teachers as they make adjustments to their lessons and teaching practices. [17,18,19,20]. In addition to PD duration, teachers in AMP! learn how to shift their current lessons to include more effective strategies such as inquiry-based and team based lessons [21,22]. Inquiry based teaching can be described as an open communication between teachers and students to freely ask questions to promote conceptual understanding and puts an emphasis on lesson engagement first to best motivate students and a theory approach to solve problems second [21]. The success of team-based learning depends on the ability to demonstrate complex tasks [22].

AMP! is designed to improve student engagement and achievement in STEM subjects by training teachers to guide students in making connections between applied mathematics and inquiry science through active, creative, and rigorous learning experiences. This approach is based on the knowledge that linking mathematics and science throughout teaching progressions creates an atmosphere where these disciplines connect more effectively [23]. Thus, regular collaboration between teachers is needed and has shown to have a positive impact on student achievement [24]. This collaboration was extended to include peer observations from content specific teachers outside their campus using a non-directive approach to observations [25].

AMP! focuses on in-service 8th and 9th grade teachers while the goal of having them inspire, motivate, and encourage students. The impact of training teachers is amplified, as one teacher over a ten-year career can interact with thousands of students. Excellent teachers have students who perform better on tests, are more likely to attend college, enter jobs with higher salaries, as well as have fewer social problems [26,27]. Among the multitude of school factors, teacher quality is the most influential in student outcomes extending beyond their academic years [28,29]. Yet, despite their vital importance, the needs of middle school math and science teachers are great. According to the National Academy of Sciences, 69% of all middle school students are taught math by teachers who do not possess a degree or certificate in mathematics [30]. This is confirmed by the analysis conducted by Horizon Research, which found that only 35% of middle school mathematics teachers had a degree in math or math education [31]. In addition, only 41% of middle school science teachers held degrees in science, engineering, or science education. Few of these teachers spent more than 15 hours on content-related professional development in the last three years [31]. It is perhaps not surprising in light of these statistics that less than half of middle school mathematics and science teachers feel well prepared and confident to teach their subject matter. This deficit in teaching translates into poor outcomes for students at a critical time in their intellectual development. To address this deficiency, AMP! provides stimulating cross-cutting PD for teachers and innovative, motivating, and culturally responsive learning experiences for students.

This demand has led educators across the country to make a shift to include more STEM in curriculum at all levels. It is well established that deep understanding is constructed when students make connections between prior knowledge and new experiences - when they see the connections [32,33,34]. An innovative curriculum that provides a crosswalk between mathematics and science can help students make connections between applications that are relevant to their lives increasing their interest and motivation and allowing deeper conceptual understanding [35]. Current research shows that strengthening mathematics and science teacher content knowledge results in substantial and sustained improvement in instruction and student achievement. Few middle school teachers have deep knowledge of the content that they are teaching and fewer still have had preservice training in integrated topics [31]. Mathematics, science, and literacy are, by nature, integrated. The Next Generation Standards have recognized this interdependency between subjects, and they are designed to support the development of college and career readiness through a focus on greater depth in content and by covering fewer standards that all support critical thinking, logical reasoning, analytic reading and writing skills [36]. By providing students with a connected curriculum, they will have stronger reinforcement of mathematics and science concepts along with more opportunities to cultivate effective reasoning and communication skills.

Professional Development Design

The Applied Mathematics Program was developed with the intention of increasing mathematics performance of students through integrating science content standards and providing context for instruction. Science was chosen as the accompanying subject area as the call to combine these disciplines whenever possible has been advised for many years [13]. Through the year-long PD program, which highlighted connected lessons between mathematics and science, constructivist pedagogy, sustained coaching, and standards-aligned lessons, the program aimed to:

- Increase mathematics and science content, as well as pedagogical knowledge of teachers by selecting pairs of mathematics and science teachers from the same campus and supporting their further enrichment through intensive PD;
- Increase student engagement and achievement in STEM with a focus on inquiry in mathematics by making connections between inquiry science and applied mathematics through engaging, creative, and rigorous learning experiences for students; and
- Create a supportive and rewarding environment to sustain teacher participants in high-needs schools by establishing professional learning communities, supporting team learning and team building, mentoring and coaching, and training to successfully implement their content standards.

Collaborative Math-Science Campus Teams

The Applied Mathematics Program supported 47 8th and 32 9th grade mathematics and science teachers from 12 school districts and 3 charter school systems. Teachers were selected based on recommendations, leadership, school need based on socioeconomic population, teaching level and subject, and partner availability. One of the major aspects of this program was the pairing of a mathematics and science teacher from the same campus for this experience. Once teacher pairs were selected, the program consisted of a one-week Summer Institute followed by a series of professional development weekend or weeknight sessions during the school year. With the Summer Institute and a series of ten academic meetings, 8th grade and 9th grade Algebra-Biology participants were provided with up to 110 continuing professional education (CPE) hours. The duration of the program was key in that sustained PD programs have been shown to have a great impact on change in teaching methodologies and, ultimately, student achievement [19].

One of the primary goals of the program was to provide resources and training so that teachers can support each other on their campus. We especially focused on helping teachers to build their content knowledge so that they are better prepared to give students exceptional educational experiences in the mathematics and science classrooms. By relying on the expertise of their partners, other educators in the cohort and program facilitators, the participants were better able to integrate cross-curricular teaching approaches. This collaborative approach has been shown to be critical in terms of design and implementation of integrated STEM teaching [37].

Starting with the Summer Institute, teacher pairs were allowed to take deep dives into their partner's content area to gain a robust understanding of which topics are traditionally taught and how they are presented. Additionally, participants worked on group projects that focused on using the major tenets of inquiry-based teaching to develop lessons with their partners that would fit into their school's scope and sequence. This experience allowed teachers to understand that they would not be building hypothetical lessons, but instead they would be developing practical ones that would actually be used during the school year.

Math-Science Integrated Inquiry Curriculum

During each of the sessions that educators participated in, instructors presented signature lessons that combined grade-level appropriate mathematics and science content standards in a fun, meaningful way. Each lesson focused on a specific mathematical concept through an inquiry-based activity designed to have students make observations and ask questions to build conceptual fluency. Through the use of hands-on and technology-based activities and group discussions around each topic, participants were able to dissect connections and brainstorm realistic ways to implement each lesson on their campus. In implementing the inquiry-based lessons and activities, particular attention was paid to helping teachers understand how inquiry-based instruction can be practical in the classroom. Additionally, a point was made to truly open the doors between mathematics and science content. Mathematics is often taught in a bubble, with little to no context, making it far too abstract for students to fully grasp in the middle grades.

Throughout the AMP! experience, teachers were assisted in building their classroom environment to support student engagement. One of the traditional methods of teaching involves the I-R-E sequence (teacher Initiation, student Response, and teacher Evaluation) of classroom communication – in which the teacher asks a question with a known answer, a student is called upon to respond, and the teacher follows with an evaluative comment [38, 39]. During this PD, teachers were moved toward more productive forms of communication such as the Explore-Before-Explain model. Participants read Jeff Marshall's *Succeeding with Inquiry in the Science and Mathematics Classroom* as a course book requirement [40]. This text beautifully illustrated the need for students doing math and science to learn math and science in a way that was received well by the teacher groups. Meaningful discussions took place throughout the program that brought this idea front and center in the classroom. By providing regular classroom constructivist or inquiry learning opportunities to discuss students' ideas collectively, AMP! teachers – and, in turn, their students – are encouraged to process, make sense of, and learn from each other's ideas, observations, and experiences. Such collaborative verbal communication forced teachers and students to think about and articulate ideas, engage in argument from evidence, critique arguments from others, reflect upon what they may or may not have understood, and practice and develop their mathematical and scientific language skills.

Content-Specific Sessions

In addition to collaborative activities for mathematics and science teachers, participants engaged in sessions that focused solely on their content area. By implementing "math only" and "science only" evening sessions throughout the course, teachers were allowed to sharpen their skills and add new teaching techniques to their toolbox. Each of these training sessions focused on how to implement inquiry-based strategies in their classrooms while still adhering to the timelines of their individual school districts. Once again, inquiry-based teaching was stressed as these teaching approaches have been shown to increase student's interest in STEM [41].

Classroom Peer Observations & Mentoring

One more pivotal requirement of program participants was to participate in two peer observations at the campus of another teacher pair as well as one-on-one classroom coaching visits from program facilitators. Peer observations focused on watching how other educators were implementing combined mathematics and science lessons and their overall inquiry teaching style. As a part of the program, various mentoring support mechanisms were provided for participants. Teachers throughout the year lauded this support, as they knew that classroom support was only an email away. When AMP! mentors conducted campus visits, a point was made to have teachers present lessons that incorporated mathematics in the science classroom and science in the mathematics classroom. These pillar lessons showed that teachers were internalizing the importance of the connections and making strides toward genuinely approaching education from a cross-curricular perspective.

Methods

Teacher Instruments and Analysis

In order to determine if AMP! achieved the goals of increasing teacher content knowledge, increasing student engagement and academic success, as well as creating supportive teacher cadres, multiple levels of assessment were utilized. The evaluation plan included qualitative and quantitative assessments to determine whether teacher changes occurred and, when possible, the level of statistical significance of those reported changes. The instruments used included the Mathematics Teaching Efficacy Belief Instrument (MTEBI) [42], a Leadership Survey created in-house, and a Needs Assessment survey also created by the team. AMP! teachers completed the three surveys before and after the program. As a general analytical strategy, t-tests/ANOVA were used to test for differences between pre vs post within treatment changes or between the treatment and comparison groups when possible. To test for statistical significance for all assessments, the alpha was set at 0.05. All data collection followed university approved IRB protocols and involved informed consent.

The MTEBI is a 25 Likert-type items on a five-point scale from strongly disagree to strongly agree. The instrument includes 12 negatively-written questions. Five points were assigned to positively worded items with the response of Strongly Agree and the other items were reversed. Hence, the MTEBI scale has a possible range from 25 to 115 points. The MTEBI measures two aspects of teaching efficacy: teaching efficacy beliefs and outcome expectancy. Teaching efficacy beliefs pertain to whether the teacher can successfully instruct students, whereas outcome expectancy pertains to the belief about whether good teaching results in student improvement. The MTEBI survey consisted of two subscales which were analyzed together and independently. The first subscale was the Personal Mathematics Teaching Efficacy Belief Scale (PMTE) with a scoring range from 13 to 65 points. The second subscale was the Mathematics Teaching Outcome Expectancy (MTOE) with a range from 8 to 40 points.

The Leadership Survey was developed in-house to align with the program goals and is divided into three parts that each focus on different aspects of leadership, as follows:

- Part 1 consists of five questions focused on facilitating presentations and working with others;
- Part 2 consists of 30 questions regarding opportunities for mathematics/science leadership activities on campus;
- Part 3 consists of three categorical questions about leadership readiness/roles/perceived administrator views.

Each portion of the survey was analyzed for pre-post differences using matched data of all AMP! teachers from both subjects and grades and math teachers only.

The Needs Assessment was designed to inform the AMP! instructors of the level of incoming knowledge of teacher participants in areas such as state standards, assessment techniques, and inquiry-focused pedagogies, as well as to measure changes over the length of the program. Each of 24 questions had four or more multiple choice options specific to the question; for some questions teachers could select all applicable answers. Questions of interest to this study are included in the tables of data with the results.

Interviews were conducted via phone by an external evaluator with 20 AMP! teachers at the conclusion of the year-long program. Interviews followed a protocol with 15 questions about their perceptions regarding efficacy in their content areas, their perceived professional leadership abilities, perceived abilities to plan and implement inquiry-based lessons, and needs with regard to teaching. The protocol for the interviews is included in the appendix, with specific questions addressed in the results section. During all interviews and notes were taken and they were audiotaped and later transcribed. The external evaluator identified emerged themes and developed units of data using descriptive qualitative method [43].

Teacher Characteristics

The main characteristics of the teachers that participated in the AMP! 2017-2018 program are summarized in Tables 1 and 2. The total number of participants in the program was 79. As shown below, the teacher sample was balanced, being almost equally distributed between the two subjects taught by teachers, for each grade. In terms of gender, there were more women than men teachers (58 female vs. 21 male). Most teachers were of either White (32) of African-American (37) racial backgrounds. Also, the majority of teachers were not Hispanic or Latino ethnicity. This demographic profile is representative for the Region IV area.

Table 1 Teachers by subject and grade level in 2017-2018 AMP!

	8th Grade	9th Grade	Total by Subject
Mathematics	24	17	41
Science	23	15	38
Total by Grade	47	32	Grand Total =79

Table 2 Gender, Race, and Ethnicity of Teachers in 2017-2018 AMP!, N=79.

Characteristic	Category	Count	%
Gender	Female	58	73%
	Male	21	27%
	Prefer Not to Provide	0	0%
Ethnicity	Hispanic or Latino	9	11%
	Not Hispanic or Latino	65	82%
	Prefer Not to Provide	5	6%
Race	African American or Black	37	47%
	Asian	2	3%
	White	32	41%
	Other	2	3%
	Prefer Not to Provide	6	8%

Student Data and Matching

In order to access student performance measures already being administered in schools, we wrote a proposal to gain access to the State of Texas Education Research Center (ERC) database. The ERC database is a product of a collaboration between the Texas Education Agency (TEA), the Texas Higher Education Coordinating Board (THECB), and the Texas Workforce Commission (TWC). The ERC database contains data on K-12 students, including state standardized test results, high school graduation information, undergraduate graduation information, college major, attendance, courses taken, profession, and many others. This database allows for the comparison of test performance for students of AMP! teachers with students of non-AMP! teachers. We used a statistical equating procedure, known as propensity score matching, to create a matched student comparison group. We matched students on a variety of demographic characteristics, including gender, race, economic status, English learning status, gifted and talented status, special education status, and at risk status. Because the database of students of non-AMP! teachers is substantially larger than the database of students of AMP! teachers, we examined models where we 1) used only the total sample of students of AMP! teachers and 2) used a bootstrapped sample where we resampled students of AMP! teachers when matching them to comparison students. Additionally, for both the non-bootstrapped and boot strapped samples we examined models that used a 1-to-1 AMP! student to comparison student match, incremented up to a 1-to-10 AMP! student to comparison student match. Because the potential set of control students was so large, we selected 10 control students to every 1 treatment student. This matching allowed us to increase our statistical power to detect effects. Additionally, we examined two different analytic samples, one where treatment and control students were sampled with replacement, and one where they were sampled without replacement. Results of all of the comparisons were quite comparable, thus, we will present only the results of the 1-to-10 AMP! student to comparison student comparisons for the non-bootstrapped and bootstrapped samples. Students were identified using a multistep matching process in the ERC database. First, AMP! teachers were linked to a database of courses that were taught in school year 2017-2018 using a masked ID. This database was then matched to a database that included the courses in which all students in SY 2017-2018 were enrolled. Finally, this database was matched to a database of STAAR test results. The STAAR is administered three times per year. As such, we only retained students' first attempt taking the STAAR. Students of AMP! teachers were then matched to comparison students. Below in Table 3, we present the counts for the 1-to-10 matches for the non-bootstrapped and bootstrapped samples

Table 3. Number of Students of AMP! Teachers and Comparison Students for Samples.

	Non-Bootstrapped		Bootstrapped	
Course	AMP!	Comparison	AMP!	Comparison
8th grade Math	2,421	24,310	14,131	141,311
Algebra I	2,456	24,560	21,329	213,332

As a final note the state standardized test is different in every grade and school year, so analyses were restricted to examining treatment and control group differences in specific grade/year pairings.

Results

Teacher Outcomes

The combined group of AMP! teachers, math and science, from both 8th and 9th grade cohorts scored significantly higher on the Leadership Survey post-test for the total score that measured leadership activities, dissemination, readiness, and perceptions (total gain of 18.8%, $p<0.05$).The teachers also showed significant change on each of the three separate parts of the Leadership Survey. When analyzed for math teachers only, the Leadership Survey changes were only significant for Part 3 that focused on leadership readiness and perceptions by school leaders, as seen in Table 5. The sample size was much smaller and the overall survey still showed significant gains.

Table 4. Leadership Survey Results for All Teachers in 2017-2018 AMP!, N=52.

	Pre		Post		Post - Pre		
Survey Portion	Mean	St Dev	Mean	St Dev	Mean Diff	St Dev	p value
Part 1	5.83	2.26	6.52	2.48	0.69	2.36	**<0.001**
Part 2	8.31	3.47	10.33	4.15	2.02	3.96	**<0.001**
Part 3	7.31	2.21	8.63	2.20	1.33	1.80	**<0.001**
Overall	21.44	6.47	25.48	7.08	4.04	6.13	**<0.001**

Table 5. Leadership Survey Results for Math Teachers in 2017-2018 AMP!, N=24.

	Pre		Post		Post – Pre		
Survey Portion	Mean	St Dev	Mean	St Dev	Mean Diff	St Dev	p value
Part 1	5.92	1.74	6.25	2.29	0.33	2.16	0.457
Part 2	8.00	3.48	9.75	3.70	1.75	4.75	0.084
Part 3	6.96	2.39	8.38	2.46	1.42	1.98	**0.002**
Overall	20.88	6.29	24.38	6.74	3.50	7.08	**0.024**

The math AMP! teachers did not show significant changes in teaching self-efficacy via the MTEBI overall or by each subscale as seen in Table 6. The overall scores did increase for the post-test, but the changes were not significant and the sample size was small.

Table 6. MTEBI Results for Math Teachers in 2017-2018 AMP!, N=25.

	Pre		Post		Post - Pre		
Survey Portion	Mean	St Dev	Mean	St Dev	Mean Diff	St Dev	p value
PMTE	57.44	6.47	58.52	4.55	1.08	6.28	0.398
MTOE	46.92	5.73	46.27	5.68	-0.65	7.61	0.665
Overall	104.68	10.99	105.08	9.14	0.40	13.04	0.879

Both the science and math AMP! teachers combined by grade and separated by grade scored significantly higher on their DTAMS math post-test compared to their pre-test which suggest increased content knowledge (gain of 13%, $p<0.05$), as shown in Table 7.

Table 7. Math Content Test Results for All Teachers in 2017-2018 AMP!

	Pre		Post		Post – Pre		
Group (N)	Mean	St Dev	Mean	St Dev	Mean Diff	St Dev	p value
8th grade (42)	14.95	7.46	16.83	9.28	1.88	5.88	**0.044**
9th grade (27)	17.93	8.79	20.41	9.71	2.48	4.63	**0.010**
All (69)	16.12	8.08	18.23	9.54	2.12	5.39	**0.002**

A few of the key questions from the Math Needs Assessment are shown in Table 8 to represent some of the changes observed in teachers over the course of the year of AMP! Significant increases were seen in teachers having their students explore new ideas hands-on first and learn vocabulary as it is embedded in engaging activities. Teachers' knowledge of state standards did not significantly increase, though teachers already reported their knowledge to be quite high at the start of the program. Teachers did report their understanding and use of inquiry to increase over the year and the change was significant.

Table 8. Math Needs Assessment Results for Math Teachers in 2017-2018 AMP!

		Pre		Post		Post-Pre	
Question	Most Ideal Response	Mean	Variance	Mean	Variance	Mean Diff	p value
In general, how are vocabulary words presented for the first time in your classroom?	Students explore the associated phenomena in a hands-on fashion and are given the appropriate words as needed	0.301	0.200	0.615	0.246	0.314	**0.0186**
In most cases, how is a new mathematics content topic introduced in your classroom?	The students explore the new concept through a hands-on activity	0.491	0.113	0.692	0.121	0.201	**0.0422**
Which of the following best describes how familiar you are with the state standards (TEKS)?	I basically know all the TEKS and what they require for my subject(s) as well as the grades above and below mine.	2.81	0.882	3.19	0.642	0.385	0.115
Which of the following best describes how familiar you are with Inquiry as a model for teaching/learning?	Every lesson I teach is based on the Inquiry philosophy.	2.08	0.794	3.00	0.240	0.923	**<0.001**

Though some statistically significant results were revealed, they should be interpreted with caution because the teacher sample size was rather small with only 79 total AMP! teachers. When only math or one grade level was analyzed, numbers were much smaller especially for paired data analysis. Therefore, statistical significance, though found, may not be valid due to the extremely small number of observations. In addition, a comparison group of teachers was not used in this study so the teacher data can only be compared pre to post for those that self-selected into the program. In the past, we had tried to incentivize teachers to participate as comparison teachers the year prior to participation in the program with very minimal interest from teachers. However, using the EdRC database, we were able to create a well-matched comparison group for the student outcomes using a propensity score matching strategy.

Interview data, from 20 interviews, half AMP! 8th grade teachers and half 9th grade participants, was analyzed and organized into twelve themes keeping the main categories of the protocol, and adding more themes that emerged throughout the analysis. Twelve overarching themes and sub-themes were identified from data analysis from 331 units of data as shown in Table 9. The external evaluator shared examples of each of these types of data units, with subcategories for some of the larger themes.

Table 9. Themes from Interviews of AMP! Teachers.

Main Categories	Units of Data
Overall experience	60
Value of the summer experience	58
Suggestions	47
Benefits of the program	32
Miscellaneous	31
Connection math-science	30
Inquiry-based elements	24
Expectations before the program	19
Challenges before being in program	18
Description of the program	7
Pedagogical skills developed	7
Content knowledge confidence	3

This paper focuses on how teachers were able to improve their math teaching practices so that their students engaged and improved their knowledge of mathematics. With that frame, the following interview data is from the most prevalent theme of "overall experience." This theme is one of the key results since it includes the responses to inquiry-based teaching, connecting science and math, and observing other teachers. When analyzing the qualitative feedback of the cohort, special attention was given to the manner in which these teachers share the experience of the program at their schools, why they consider this program a positive experience, their opinions about the instructors, how they plan to apply the program to the next school year, and the impact of having access to resources and hands-on materials. Verbatim teacher comments that support each of those subcategories that emerged from the theme analysis follow:

- Sharing the experience: *I guess something I enjoyed too was going to see other campuses, when they made us do that, that opened my eyes to what they were doing; at the same time, when they came to visit us, it kind of reaffirmed some things about what we were doing well.*
- Positive overall experience**:** *I did change it to the point where I'm not so scared to incorporate the science in my lessons. I knew that we want to do cross curriculum, but I'm like "hmm I really wasn't going to do it because I don't know anything about Biology". But with doing the AMP program, it gave me the confidence to actually do it, and then my students loved it too.*
- Positive overall experience*: So, I'm really trying to preserve my voice. I'm crying now. This program turned me back on to education. I recommend this program for first year teachers, for teachers who have been teaching for a long time, like maybe ten year-old teachers who feel like they are an expert in teaching. Just so that they don't lose it and they can continue to grow.*
- Program instructors and mentors: *Most times when teachers go to conferences they tell us what do for our students, but when we get to professional development they don't really apply what they teach. So I felt like ours was different in that every time you go it was something hands on. They always kept us engaged, it was never boring.*
- Program instructors and mentors: *[The facilitators] were willing to play the role of the facilitator and us be the students but not make us feel like we didn't*

know what we were doing. This has been an understanding of how the process feels. I wouldn't change anything about who is carrying out the job and who the facilitators are or who the mentors were.

- Applying the program to next school year: *Having that content professional development [was good]. When you're doing something and then going back into the session. It's not like oh we did one session, and then you forget about it. So by going back and kept going to the sessions, even if your interest kinda dropped off or you got busy or whatever, you go back and you get something else and it kinda re-energized. Honestly, it just kinda kept the momentum going throughout the whole year.*
- Hands on materials/resources: *Having hands on experience myself with working on some of the lessons, and utilizing the program before I set it in front of my students really helped me be more comfortable.*
- Hands on materials/resources: *[AMP!] provided, not only the opportunity to see it from different grade levels, it provided the materials that could be adapted and edited to what you have in the material on your campus; as well as getting input and having opportunity to observe other teachers using the exact same thing, so that you can really build professionally on that part too. So, the program was very beneficial.*

Additionally, when commenting on the structure of the program, one of our teachers remarked that "Wednesday night meetings helped to deepen understanding of topics that could be used later in the classroom without a lot of prep work." Yet another teacher stated that "This program has helped me become a stronger teacher, and showed me that I can push students to reach their maximum potential through inquiry and other strategies." An additional teacher added that "I loved learning ways to build math thinkers and I love being broken out of my shell." While many conversations with teachers seemed to confirm that many saw the benefits of both types of sessions, some greatly gravitated towards the content-specific sessions. The feedback often spoke to the desire to become stronger in the subject area in which they teach.

Furthermore, the teachers loved being able to interact with other educators from the greater metropolitan area. Teachers shared comments such as "We are currently in transition on my campus, the AMP! program allowed a structure and creative environment. I need to come up with new ideas. The AMP! program allowed me to sit with other like-minded individuals to think of new creative ways to reach students at my Title I campus" and "I really enjoyed meeting other educators who wanted to be better. It was a great group of people (both staff and teachers) to work with and get to know. It was a good learning experience to hear about how things are at other campuses and districts, and how such a diverse group of people think about teaching and education." Yet another teacher added "I enjoyed interacting with math and science teachers from all over the [metropolitan] area. I rarely get to collaborate with teachers from other districts and it was empowering to get best practices from them."

Student Outcomes

The evaluation of student scores on state mandated exams shows that the students' scores were high for students of AMP! teachers for 8th grade Math and Algebra I State of Texas Assessment of Academic Readiness (STAAR) tests. The AMP! teachers' students significantly outperformed non-AMP! teachers' students on the Algebra I exam for both non-bootstrapped and bootstrapped sampling methods, as shown in Table 9. While the students of AMP! teachers scores were higher than the comparison students for 8th grade Math, the difference was not significant. Thus, it may be that 8th grade students of AMP! teachers do perform better than comparison students on the math assessment, but the advantage is quite small.

Table 9. STAAR Test Mean Score Comparisons of Students of AMP! Teachers and Comparison Students.

	Non-Bootstrapped			Bootstrapped		
Course	AMP!	Comparison	Difference	AMP!	Comparison	Difference
8th grade Math	1,663.6	1,662.3	1.2	1,679.6	1677.5	2.1
Algebra I	4,065.3	3,954.7	110.6*	4,049.0	3,964.0	85.0*

Summary and Discussion

This study had the goal of determining if student success in mathematics would be impacted by having educators participate in a sustained, team-based professional development program that focused on using inquiry and collaborative pedagogical approaches while integrating science concepts in mathematics classrooms. Additionally, the improvement of teachers' content knowledge and teaching self-efficacy were considered. To determine the effectiveness of the program, we analyzed three different measures: 1) participant's feedback from leadership and teaching readiness surveys and interviews, 2) teacher's performance on content post-tests (DTAMS), 3) students of participating teachers' performance on the state standardized mathematics assessment (STAAR). As shown in the previous data, students of teachers in AMP! outperformed comparison students on Algebra I (significantly) and 8th grade mathematics standardized tests and participating teachers had significant gains in Algebra content post-tests, as well as leadership assessments.

Teachers improved their algebra content knowledge based on the DTAMS test by 13%. However they did not improve in math teaching efficacy, which may in part due to the structured approach of AMP! The following factors of the program would have been those to enhance teacher understanding of math concepts 1) participation of the teachers in the program in their math-science collaborative teams, 2) math-science integrated inquiry curriculum, and 3) content specific sessions. While this knowledge may have increased, teachers might have also realized their own gaps in understanding during these activities, which may have contributed to not seeing significant gains in math teaching efficacy. Also, the classroom peer observations and mentoring may have provided needed feedback to teachers that is not a norm of most middle and high schools. Math teaching efficacy increased slightly in personal teaching efficacy, as teachers had a multitude of experiences to enhance their teaching strategies. However, outcome expectancy of their students decreased. Our other PD programs have sometimes seen similar trends, which we attribute to the teachers not having had time to fully integrate the ideas presented in AMP! within the year of the program. We expect following up on teachers in years after the program might show outcome expectancy gains as teachers are able to work an entire school year with math-science integrated concepts and inquiry-focused lessons.

Participating in this program with another teacher from the same campus allows the team to have conversations about content being presented while they attend the PD sessions and back on their campus. These candid conversations can contribute to a better understanding of concepts being covered. In the case of mathematics educators, they often had to discuss content standards and topics with their science colleagues to allow them to understand how to answer questions that may arise during the implementation of AMP! lessons. This partnership was coupled with the opportunity to have content-specific sessions, where educators were able to strengthen their mathematics skills by interacting with both grade-level standards and vertically-aligned content from upper grades. This process of explaining content to peers and working in a cohort-within-a-cohort of math teachers had a positive impact on mathematics teachers' own content knowledge as displayed on post-testing.

Another integral component of the program is the integrated inquiry curriculum that the teachers experience during a sustained PD program. The integrated approach to curriculum solidifies understanding of concepts and makes connections between content. Providing context for mathematics, in the form of science topics, allows students to see the interconnectedness of the subject areas and allows the same concepts to be addressed by multiple teachers throughout the school year. Mathematics educators spoke to this context helping to create interesting lesson plans and activities for their students and ultimately an increased self-efficacy in facilitating mathematics courses. Finally, the classroom observations by AMP! staff allow for immediate feedback and mentoring to the teachers involved in the program. AMP! staff have the opportunity to collaborate and mentor teachers in their classrooms while observing participants implementing their learning and understanding of the concepts taught during AMP!. This mentoring provides support for teachers and immediate feedback thus strengthening concept and content development by the teachers.

In our investigation of student standardized test performance, we found that AMP! students significantly outperformed control group students. Because we found that students in AMP! teacher classrooms outperformed other students, we want to theorize about why the program had this impact. Teachers of AMP! students have a greater understanding of content knowledge based on their participation in the year-long PD program as well as improved pedagogical approaches to teaching mathematics. This directly affects the students in their classrooms as they have more confidence and skills to teach mathematics in an inquiry approach. Students are allowed to construct their own meaning to concepts being taught thus enabling them to gain a deeper understanding of the content. Integration of mathematics and science has shown to impact critical-thinking skills and the ability to reason logically in the classroom [8]. The integrated math-science curriculum also allows students to see connections between the content and experience concepts in multiple classrooms therefore improving their learning and thus standardized test scores.

Next Steps

Moving forward, the Applied Mathematics Program will attempt to recreate the model described at lower grade levels. Focusing on fifth, sixth and seventh grade teachers will have the benefit of impacting a larger pipeline toward Algebra I success. Conceptually, the target audience for these expanded efforts would be schools which have had teachers participate in the program in the prior years as to create a community of practice within the campus. Recruitment efforts will be focused on catering to larger groups of teachers from the same schools across grade levels. Additionally, a future goal of AMP! is to increase the capacity to offer this program virtually by continuing to modify the curriculum to provide online options for all of our lessons and activities. With the constantly shifting landscape of education, it is important to be prepared for all types of classroom environments (face-to-face, hybrid, online, etc.) This shift to a collection of virtual options may even open the door for professional development programs that extend outside of the metropolitan community to impact a wider range of students/teachers.

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