Teacher and Student Content Knowlege Gains: Effects of a Materials Science-Focused Professional Development Program

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Abstract

The Professional Development for Materials Science-Focused High School Courses program aims to give educators tools rooted in materials science to expand their teaching methodology and inquiry-based learning techniques. Now in the fifth year of the program, the current format includes a forty-hour intensive ASM summer camp for teachers preceding the academic year, an online two credit hour graduate course on the fundamentals of materials science, in-classroom support to aid teaching and experimental methods, and full group meetings four times throughout the academic year. Teacher outcomes from the beginning to the end of the academic year are assessed by evaluating content knowledge and changes in teaching pedagogy and efficacy. Student outcomes are evaluated by assessing their content knowledge and interest in science. Previous results through a pre-post single group research design indicate the program showed established increases in teacher content knowledge, as well as increased use of materials science activities in the classroom. Preliminary analysis of the pre-assessment data allows baseline comparison of teacher and student data between the treatment and control groups. This analysis includes baseline analysis of teaching pedagogy and efficacy, teacher content knowledge, and student content knowledge. The pre-assessment of teaching pedagogy and efficacy did not show a statistically significant difference in scores for the teachers in the treatment and control groups. For the students, there was no statistically significant difference in baseline knowledge for those taught by first year teachers in the program and control teachers, however for the teachers, there was a statistically significant difference in content knowledge between the treatment and control teachers. The team will work to understand this difference for the teachers in the coming year to obtain more comparable groups. This analysis seeks to determine the efficacy of the professional development program at increasing teacher and student knowledge and to quantify the changes in teacher practice.

Keywords

Materials Science, High School, Teacher Professional Development

Introduction

The Professional Development for Materials Science-Focused High School Courses program (here after just called the program) provides over 120 hours of professional development (PD) to Ohio high school teachers through a summer workshop and additional meetings during the following academic year, preparing the teachers to implement a materials science curriculum, hands-on activities, and guided inquiry pedagogy in their classrooms. The program is funded by the U.S Department of Education's Math and Science Partnerships (MSP) program. Materials science provides accessible, hands-on lessons, and it can tie together traditional physical science classes (Guskey, et al, 2009). The program builds on the established success of weeklong summer camps hosted by the ASM Materials Education Foundation (ASM) to provide *sustained* support for teachers as they make curricular and pedagogical changes. The desired outcomes of

such professional development programs include deep understanding of the materials science content by both teachers and their students (Desimone, et al, 2002).

The program began in summer 2012 and initially focused on 9th grade physical science teachers and their courses. Over the course of the first 3 years, several teachers who persisted in the program began to offer materials science as an elective course in their schools. In 2015, the focus of the program switched to teachers offering or seeking to offer such elective courses in their schools. Prior to the 2016 to 2017 cycle, the program showed established increases in teacher content knowledge, as well as increased use of materials science activities in the classroom using a pre-post single group research design (Polasik, et al, 2016). In the 2016 to 2017 academic year, teacher and student content knowledge increases are being assessed relative to a comparison group of teachers using a quasi-experimental research design. Increases in teacher content knowledge are tracked to student content knowledge and teaching practices. Reliability and validity of the teacher and student concept assessments will be discussed, as well as relationships between the different measures of teacher practice. Thus, it has broader implications for future extension of the program to include a greater number of teachers, across a wider range of geographical areas.

Methodology & Measurements

The first three years of the program (Autumn 2012 – Spring 2015) tested different tools to determine a program with components best equipped to educate the participating teachers, create a professional learning community, and impact teacher practice. Based on established research and the program's theoretical model, this would empower the participants to teach materials science concepts effectively to their students. Twenty to thirty teachers have participated annually. Additionally, treatment teachers can participate in the program for multiple years. The 2016-2017 iteration of the program has been developed with a quasi-experimental design, where in addition to collecting data from treatment teachers participating in the professional development program, data is also collected from control teachers who are not participating in the professional development activities. There are eight control teachers and twenty treatment teachers in the 2016-2017 cohort. While there is not a control teacher matched to each of the twenty treatment teachers, the eight control and treatment teacher match pairs are similar in terms of years of teaching and age.

Table 1: Overview of Teacher Demographics

Program Year	**2015-2016 Treatment**	**2016-2017 Treatment**	**2016-2017 Control**
# Participants	25	20	8
# Returning	4	5	0
# 2+ Years in MSP	13	3	0

Beginning in July, the treatment teachers participate in 120 hours total of activities that include the 40-hour summer ASM Camp, four full-day group meetings over the course of the academic

year, one-on-one classroom support provided by an experienced materials science high school teacher, and a two credit hour online graduate course. The professional development materials are provided to the teachers in a variety of forms, span the course of the year, and evolve to best address the needs of the participating teachers. To understand the effectiveness of the professional development activities on the teachers' understanding of the material, several tools were administered to both the treatment teachers and the control teachers at the beginning and the end of the academic year. These assessments include the *Teacher Beliefs and Attitudes Survey, The Survey of Enacted Curriculum (SEC),* and the *Teacher Materials Science Concept Inventory.* To understand the effectiveness of the teaching to the treatment and comparison students, the *Student Materials Science Concept Inventory* was administered to both groups of students (Polasik, et al, 2016).

The quasi-experimental evaluation data provided qualitative assessment of the value of the professional development program, as well as ways to improve the professional development and assessments in future iterations of the program. Preliminary analysis of the pre-assessment data allows baseline comparison of teacher and student data between the treatment and control groups. This analysis includes baseline analysis of teaching pedagogy and efficacy, teacher content knowledge, and student content knowledge.

Teaching pedagogy and efficacy:

For each of the entries in the *Teacher Beliefs and Attitudes Survey*, a baseline comparison was made between the control and treatment teachers. The questions were then used to determine a subscale, combining like questions for analysis. The subscales include questions addressing student engagement, instructional strategies, and classroom management. Where there was a materials science subscale equivalent, the science efficacy subscale score was compared to the materials science subscale score to see whether there was a difference between the two. The preliminary test of equivalency performed comparing the treatment and comparison teachers for science efficacy and materials science efficacy is shown in Table 2.

Table 2: Descriptive statistic comparison between science efficacy and materials science efficacy between treatment and control teachers.

		Mean	Standard Deviation	Sample Size
Science Efficacy	Comparison Teacher	4.5134	0.31219	9
	Treatment Teacher	4.5195	0.36013	19
	Total	4.5175	0.33963	28
Material Science Efficacy	Comparison	3.8889	0.54287	9
	Treatment	4.1250	0.72529	19
	Total	4.0491	0.67129	28

For both teacher content knowledge and student content knowledge, the baseline equivalence was analyzed for the control and treatment groups. The comparisons were based on the number of correctly answered items in the corresponding content assessments.

Discussion and Conclusion

From the preliminary results, comparisons were made between the treatment and control teachers and students participating in the 2016-2017 program. Similar analysis will be carried out at the conclusion of the 2016-2017 program, incorporating post-year assessments to ensure data validity.

Initial analysis of the teacher content knowledge provides insight into the differences between control and treatment teachers, as well as an understanding of any increases in content knowledge over the course of the ASM summer camp. Treatment teachers scored statistically higher relative to those who were in the control group. From the pre-camp data, the treatment teachers scored almost two times as many items as those in the control group. Similarly, first year treatment teachers scored statistically higher relative to those who were in the control group. Both parametric and nonparametric analyses conclude that the two groups (control and comparison groups) are not equivalent on their baseline content knowledge. However, the treatment and comparison groups are congruent with respect to demographic statistics such as teaching experience and licensure, education, and courses taught. Table 3 shows the overall concept inventory statistics for the comparison teachers and the subset of teachers in the first year of the program who took the test before attending the ASM summer camp. The baseline content knowledge for those teachers new to the program was higher than for the comparison group even before any formalized materials science training was received. Comparison teachers were recruited by participants from other teachers in their district, and typically taught either chemistry or physical science. Focus groups conducted in April 2017 indicated that the recruitment efforts on the part of the treatment teachers heavily considered the experience level and subject matter taught by the comparison teachers being recruited with no attention paid to their undergraduate education or prior knowledge of materials science-specific concepts. Future investigations will seek to probe the factors that influence baseline materials science knowledge or a teacher's ability to intuit solid state chemistry concepts from other knowledge. It is also possible that teachers who decide to pursue professional development in this area are influenced by prior exposure to the material (for example, by teachers in their district who teach materials science or workshops attended earlier in their career).

Table 3: Descriptive Statistics comparing the baseline content knowledge of teachers in control group and treatment group. Parametric and nonparametric analyses confirmed that the control group of teachers was significantly less knowledgeable about materials science. This was true both when the treatment group included all teachers and only new teachers.

Dependent Variable: Pre-camp Number of Items Correct

Are you a Materials Science PD program participant or are you a control teacher?	Mean	Std. Deviation	N
I am a control teacher. I do not participate nor plan to participate in the PD sessions scheduled this academic year.	12.38	3.852	8
I am in the Materials Science PD sessions to be scheduled throughout this coming academic year.	20.83	3.189	6
Total	16.00	5.547	14

Comparing primary results from the student concept inventory helps understanding of initial conditions of the students in the study, as well as an understanding of the subset of students that are in materials science classes. For the case comparing all treatment students with all control students or the case comparing all treatment students in materials science classes to all control

students, the students' baseline knowledge is statistically different, but the magnitude of the difference is not meaningful. Comparing only the treatment students taught by year one teachers to the control students, the students' baseline knowledge is not statistically different in terms of their materials science knowledge. Finally, comparing the treatment students in materials science classes taught by year one teachers to all control students, there is no statistical difference. For all cases, there is no meaningful statistical difference in baseline content knowledge of the student in the treatment and control groups. Post-year student results will be analyzed for differences in student content knowledge over the course of the year to evaluate whether the intervention of the PD program led to gains in student content knowledge.

Table 4: Descriptive statistics comparing the baseline content knowledge of students in the treatment and control groups. Parametric and nonparametric analyses confirmed that the groups are equivalent on the basis of content knowledge.

Dependent Variable: Number of items correct - Pre

TREATMENT	Mean	Std. Deviation	N
Control Group	9.34	3.301	278
Treatment Group	10.22	4.024	974
Total	10.03	3.891	1252

Control and treatment teacher were equivalent at baseline of efficacy beliefs. This holds true for all treatment teachers and the subset of first year treatment teachers. Efficacy will be compared using the end of year survey administration. SEC data will also be incorporated at the end of the year to understand teacher practice.

There are several limitations revealed by this analysis. The treatment teachers had more materials science content knowledge before participating in any professional development. While there were no statistically significant average content knowledge improvements from pre-camp to post-camp for the treatment teachers who participated in the ASM summer camp, both will be compared to post-year content assessments. Previous analyses of teacher content knowledge shows that the year-long program plays an important role in increasing and cementing teachers' understanding of the concepts covered in the ASM summer camp.

Once the post-year data is compiled, the evaluation will be run to account for the pre/post results for the entire academic year. We anticipate there will be attrition of the sample for both the students and the teachers. There were several limitations to the data collection process. We have had attrition of a few teachers throughout the year who did not have time to complete the program once the school year began. Another contributing factor was that due to late recruitment from uncertainty with the funding, our sample size for participating teachers was lower. Since recruitment was started in early summer, many teachers were unreachable and some districts were interested, but it was too late to get them on board for the academic year. For student data, there was varying levels of compliance. Some teachers were able to get data back easily, others had difficulty getting the signed permission forms to use their data, so we have a very small sample from these teachers. Additionally, several schools have a transient population, and many students that took the pre assessment have moved before the end of the academic year.

We are continually refining our recruitment process both for participating teachers and comparison teachers. This year, we have developed a multi-pronged plan for the program based on whether funding is renewed, or a strategy to keep it going on a greatly reduced budget if we

do not obtain renewal funds. We have already begun recruitment, and are strategically recruiting Career and Technical schools across Ohio as they seem to be able to more readily incorporate Materials Science. We are also reaching out directly to the districts that were interested last year, but were contacted too late.

The analysis presented provides an understanding of the teachers and students in the 2016-2017 iteration of the Professional Development for Materials Science-Focused High School Courses program at baseline. Knowledge gains for the teachers and students and teacher practice will be part of future analysis to understand the impact of the extensive intervention over the course of the year.

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