

Impact of Chemistry Teachers' Knowledge and Practices on Student Achievement

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Abstract. Professional development programs promoting inquiry-based teaching are challenged with providing teachers content knowledge and using pedagogical approaches that model standards based instruction. Inquiry practices are also important for undergraduate students. This paper focuses on the evaluation of an extensive professional development program for chemistry teachers that included chemistry content tests for students and the teachers and the impact of undergraduate research experiences on college students' attitudes towards chemistry. Baseline results for the students showed that there were no gender differences on the achievement test but white students scored significantly higher than non-white students. However, parent/adult involvement with chemistry homework and projects, was a significant negative predictor of 11th grade students' test chemistry achievement score. This paper will focus on students' achievement and attitude results for teachers who are mid-way through the program providing evidence that on-going, sustained professional development in content and pedagogy is critical for improving students' science achievement.

Keywords: professional development, chemistry education, gender differences

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INTRODUCTION

After a decade of funding projects focused on changing mathematics and science K-12 education systems at state, rural, urban and local settings [1] the National Science Foundation re-focused monies towards Math-Science Partnerships. Part of MSP's goals was to meet the challenges imposed on the K-12 education system by the instigation of No Child Left Behind legislation. NCLB required that students and teachers met standards, schools and districts were being held accountable for the academic performance of their students in core areas such as mathematics, reading, language arts, science and social studies. And a key assumption was that teacher content knowledge was critical in student achievement. For the first time in the United States, a term 'highly qualified' was defined and used to describe teachers' qualifications.

Concurrent with the establishment of NCLB and MSP, was a report from The National Commission on Mathematics and Science Teaching [2] (or the Glenn Commission). The report noted the following: 1) that the nation's future depended on students' mathematics and science education; 2) U.S. students were not competitive in these two areas; 3) improved teaching and teacher preparation was critical in improving student achievement and 4) commitment to three goals would improve education. Those goals were 1) establish a system to evaluate the quality of

mathematics and science education; 2) increase the number, and improve the preparation of mathematics and science teachers and 3) improve the working climate for mathematics and science teachers.

Importance of Teacher Professional Development on Student Achievement

In the United States, teachers' professional development programs have changed from isolated, idiosyncratic, short term efforts such as two-hour workshops to sustained, on-going experiences that engaged teachers with both science content and pedagogical innovations [3,4]. Professional development programs aimed at improving teachers' content knowledge and promoting inquiry-based teaching are challenged with providing teachers content knowledge and using pedagogical approaches that model standards based instruction [5]. Studies have shown that student achievement is positively correlated to teacher content knowledge. However, this is just one facet of what effective teachers need to know. In addition to content knowledge, teachers also need knowledge of learners and the socio-cultural context, the curriculum and teaching [6].

PennSTI [7] developed as a masters program that would provide sustained, long term professional development focus on improving teachers' content knowledge, the socio-cultural aspects of learning and

teaching through the use of inquiry and innovative teaching practices, teachers' action research and the development of an understanding of how students' learn chemistry. To achieve these goals, a cohort of twenty teachers enrolled in eight chemistry and two chemistry education courses over three summers and two academic years. The eight chemistry courses included general chemistry and two courses in organic chemistry, one course in information technology and experimental chemistry, environmental chemistry, inorganic chemistry, molecular spectroscopy, biochemistry and molecular chemistry, and a capstone, seminar course. During the summer, courses meet four times a week for approximately six weeks, five hours per day. Throughout the academic year for two Saturdays per month, the teachers completed a chemistry and a chemistry education course.

This paper reports initial results from the first, of four teacher cohorts, enrolled in the masters degree in chemistry education.

RESULTS

As part of a comprehensive evaluation, teachers and their students completed questionnaires and achievement tests. The high school teachers' chemistry test had 60 multiple-choice questions on general, organic, inorganic, biochemistry, environmental chemistry and spectroscopy. Program faculty

developed the test questions and the project's external evaluators used Rasch analytical techniques such as differential item functioning and mis-fit to revise and establish test psychometrics. Twenty-one items from the initial test were used as anchor items in the Rasch analysis. A Rasch measure of zero indicates that a teacher incorrectly answered all questions, while a measure of 100 indicates a teacher answered all questions correctly. For several reasons, item Response Theory (IRT)—Rasch Model—was used to generate scores and researchers used those scores to analyze the data. First, the Rasch measure statistically allows for comparisons across cohorts and geographical locations. Second, a Rasch score is a reflection of the person's ability and the item's difficulty. Third, a Rasch score is an equal interval measure and reflects the data linearity that is assumed for parametric analysis. Cronbach alpha's reliability for the teachers' content test was 0.85.

Table 1 shows the pre-program and final (after completion of the masters' degree) results for the first cohort (A) teachers' Rasch mean scores on the chemistry achievement test. There was a statistical significant difference between the teachers' Rasch mean score on the test ($X=45.16$) before commencing the program compared with scores after program completion ($X=56.55$).

TABLE 1. Rasch Mean Scores of Cohort A MCEP Teachers' Content Tests: Pre Program (Spring 2005) and Final (Fall 2007)

Year	N	Mean (SD)	t-value
Pre (2005)	17	45.16 (6.17)	7.67****
Final (2007)	17	56.55 (7.07)	

**** $p < .0001$

Teachers selected a typical class of their students to complete a questionnaire and content test before the teachers began the professional development program. The High School Chemistry Conceptual Content Test (HSCCCT) has 13 multiple-choice questions and six open-response items. The HSCCCT has a Cronbach alpha value of 0.60. A Rasch analysis of the test was

conducted using all item types (multiple-choice and partial credit) [8]. Table 2 shows the students' Rasch mean scores on a high school chemistry content test, possible scores were from 0-100. There were no differences between white and non-white students' mean scores.

TABLE 2. Rasch Mean Scores of Cohort A MCEP Student Content Tests by Student Group: Post Year 2 (Spring 2007)

Group	N	Mean (SD)	t-value
Non-White	64	42.72 (14.88)	-0.40
White	91	43.54 (8.16)	

* $p < .05$

In addition to the content test, the high school chemistry students completed a questionnaire that collected demographic data and students' perceptions of teaching/learning activities inside and outside of the science class. There are five subscales ("What I do," "What my teacher does," and "At least one adult in home", "What my friends do in science and the "My attitude towards science") using a Likert-type scale, ranging from Almost Never (1) to Very Often (5), for the four subscales (student classroom behaviors, teacher classroom behaviors, peer involvement in

science, and adult/parental support of student's science studies). Items assessing student attitudes toward science use a different five-point Likert scale, with values ranging from Strongly Disagree (1) to Strongly Agree (5). Using the Rasch model, the raw scores are converted to a linear scale that ranges from 0-100. Table 3 shows a significant difference between White (X= 60.63) and Non-White (X= 55.66) male students' perceptions of "What my teacher does". There were no significant differences between groups on other subscales.

TABLE 3. Rasch Mean Scores of Cohort A MCEP Student Perceptions' on "What my teacher does" by Male Student Group: Post Year 2 (Spring 2007)

Group	N	Mean (SD)	t-value
Non-White	63	55.66 (13.79)	-2.40*
White	58	60.63 (8.00)	

* p<.05

DISCUSSION

Initial results suggest that teachers' chemistry content knowledge improves after completing the masters program. Currently, the project is waiting for post-program results for the teachers' high school students to ascertain if teachers' improved content knowledge is predictive of students' chemistry achievement.

High school students' results on the chemistry achievement test showed no significant differences between White and non-White students. However, in contrast to other research that noted that teachers' use of standards based teaching practices (for example, the use of inquiry, alternative assessments, asking students to support their answers using data) were significant for African American male middle students' achievement [9] non-White male students report that their teachers are less likely to use those practices compared with their White peers. While a majority of the White students are African American, one possibility is that there is enough diversity in the sample to influence these results. Another possibility, is that of the different groups in the high school classes, that is, girls or White students, non-white male high school students are less likely that their peers to ask questions, or engage with their teachers or peers. They also may be less influenced by their teachers' practices. Importantly, that their lower reported teacher practices has not negatively impacted their achievement.

CONCLUSION

This paper reports the achievement results from the first cohort of teachers and their students in a masters program in chemistry education. There are currently another three teacher cohorts at various stages and more data is forthcoming on the impact of their improved content knowledge on their students' achievement and attitudes towards science. Because the evaluation has converted raw scores to Rasch scores, the project team can compare results from different students from various geographic locations and time samples.

After completing a masters degree focused primarily on improving their content knowledge, teachers' achievement improved. However, as previously noted, [6] content knowledge is only one facet of knowledge that teachers need to teach students. Other areas include an understanding of the socio-cultural teaching and learning context, the curriculum, and the students' diversity and learning needs. Other aspects of the project's evaluation and research agenda address these issues, for example, the chemistry teachers' implementation of various strategies to engage students in the learning process that are not assessed on the questionnaire.

These are preliminary results, with the project waiting for final student data to begin comparisons across the teachers' progression through the program, as well as cumulative results from more than one teacher cohort. However, initial results suggest that PennSTI is achieving one of its goals to improve

student knowledge in chemistry and teachers' content knowledge and pedagogical practices through extensive and prolonged professional development.

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