THE EFFECTS OF AN INTEGRATED MATHEMATICS PROFESSIONAL DEVELOPMENT PROJECT[1]

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Abstract: This study was designed to investigate the effects of an integrated reform-based mathematics curriculumon student achievement and to contextualize these outcomes in a state-funded professional development program. Program elements includeda summer program, follow-up workshops, online collaboration, and monthly site based support with instructional coaches. The study was also designed to compare and contrast teachers' implementation of the curriculum based on their participation in various components of the professional development. A mixed methods design was used, consisting of hierarchical linear modeling, followed by qualitative data analysis to explore teachers' implementation in greater detail. Results show that students enrolled in integrated mathematics performed as well or better than students enrolled in subject-specific mathematics and sustained professional development is critical to faithful implementation of the integrated curriculum.

Keywords: professional development, curriculum, student achievement, implementation

1 Introduction

Reform efforts in mathematics have lead to the creation of curricular materials that focus on strengthening the mathematical knowledge of all students and are guided by instructional practices that promote problem solving, communication, reasoning, and creating mathematical connections (Senk &Thompson, 2003). However, it is difficult to discuss the impact of these curricula when teachers are not provided with necessary support. Implementing reform mathematics curricula represents a challenging transition for many teachers (Ziebarth, 2003). We cannot expect curricula to be tossed into the hands of teachers without a structure for supporting them in their use of the materials. The National Research Council (NRC) (2004) contends teachers need adequate professional development*before implementing* new curricular materials, continued support *while implementing*, and time for reflection *during and after implementation* (p. 46). Professional development designed to assist teachers before, during, and after implementing reform curriculum has been shown to be effective (Krupa & Confrey, 2010), however teachers still face difficulties when implementing curriculum for the first time (Krupa, 2011).

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While studies of curricular evaluation may report on professional development experiences, and the NRC (2004) argues for the importance of gathering such data,few studies provide adequate detail to position those treatments in light of research on effective professional development. As a result, this study provides an account of the impact different components of a professional development, designed around the *Core-Plus* curriculum, have on students' state test scores and on teachers' implementation of the curricular materials. Specifically, the research questions to be addressed are: *(1) For teachers who participated in the project workshops, is there evidence of differential impact on student performance on state tests between teachers using the Core-Plus curricular materials and those who use subject-specific curricula (taught as Algebra I, Geometry, Algebra II)? and (2) Are there differences in teachers' implementation of Core-Plus based on varying levels of participation in a specialized professional development?*

2 The Curriculum Under Study

In 1992 the NSF awarded five-year grants to four comprehensive high school curriculum projects (Schoen, Hirsch *et al.*, 1998; Schoen & Hirsch, 2003), one of which is the *Standards*-oriented curriculum *Contemporary Mathematics in Context*(Coxford, Fey *et al.*, 2001) developed by the *Core-Plus Mathematics Project* (CPMP). Field-tested in 1994-1995, the CPMP program integrates Algebra and Functions, Geometry and Trigonometry, Statistics and Probability, and Discrete Mathematics into a three-year curriculum designed to meet the needs of all high school students, with an optional four year calculus preparation course (Hirsch, Fey *et al.*, 2008). Five design features of the curriculum were: 1) multiple connected strands, 2) emphasis on mathematical modeling, 3) access for all students, 4) full use of graphics calculators, and 5) active learning experiences for students (Coxford & Hirsch, 1996). Another key tenet of the curriculum was to have students learn to regularly communicate mathematical ideas. (Schoen, Bean *et al.*, 1996). The second edition of *Core-Plus* was released in 2008 and continued to build on the student-centered investigations of the first edition. It also incorporated a technology component with the addition of the *CPMP-Tools* software.

3 The Professional Development Project

The North Carolina Integrated Mathematics Project (NCIM) was developed to create and support a community of teachers using the *Core-Plus* curricular materialsparticularly in high need schools. Spread throughout rural parts of the state, the seven partner schools were identified as low-performing. Approximately 76.65% of students at each of the NCIM schools qualified for free and reduced lunch, and the ethnic make-up consisted of: 0.80% American Indian or Asian, 4.66% Hispanic, 17.30% White, and 77.24%0 Black.

The aim of the NCIM project was to educate teachers about the content and pedagogy of using integrated mathematics by creating a sustainable professional development model. The model of professional development included: a summer program, two follow-up workshops each year, visits from content specialists, and a collaborative website (Figure 1).

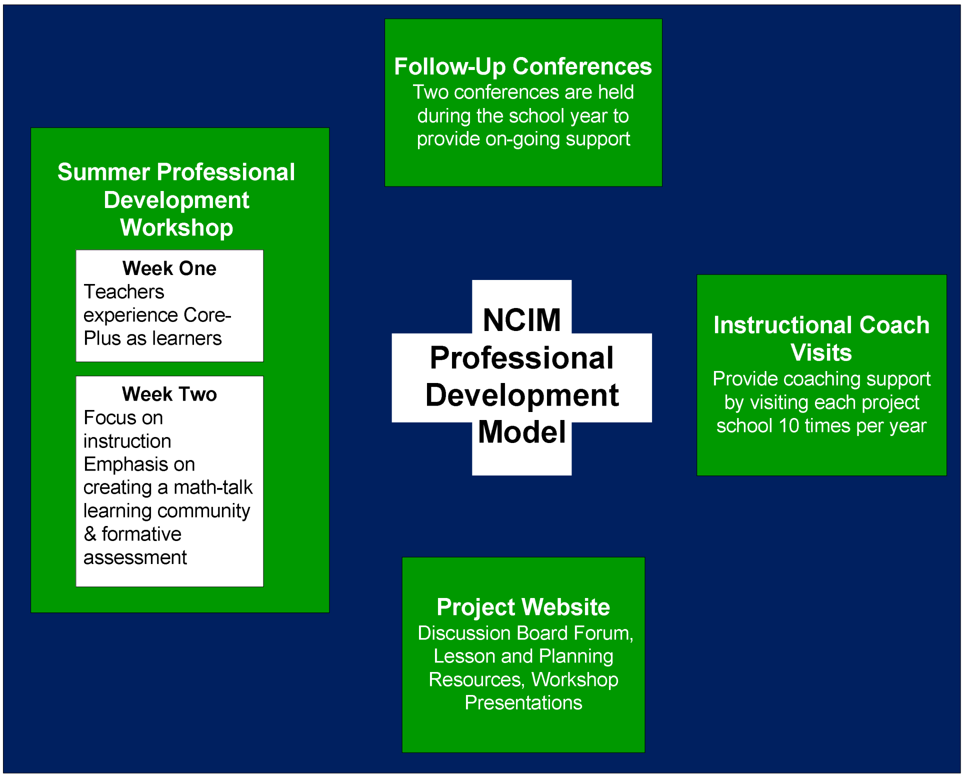

Figure 1 – Four components of the NCIM professional development model.

One-week residential Summer Workshops were held in 2008, 2009, and 2010 and were focused on using the curricular materials. Teachers were provided with first-hand opportunities to experience specific courses of the curriculum as students working through the investigations. In 2009 and 2010, a second week was added to the Summer Workshop to focus on pedagogical considerations of teaching reform mathematics. During the academic year, 2008-9, data observation reports showed teachers were still using largely the same traditional instructional practices they experienced as students (Confrey, Maloney *et al.*, 2008). As a result, the second week was designed to focus on how to promote discourse in the mathematics classroom, utilize formative assessment techniques, and effectively use collaborative groups. While the workshops were designed around the *Core-Plus* curriculum, there were teachers involved in the workshops that taught the subject-specific sequence.

One aspect of the project was to assist rural schools in establishing statewide collaborations to address the challenges of isolation. A web-based learning portal was designed to support communication and sharing of resources among the teachers, instructional coaches, project directors, and researchers. The web-based environment had resources for implementing *Core-Plus* and a discussion board that created a teacher communication network.

The third component of the model included follow-up conferences to the Summer Workshop. Teachers came back together for one-day in the fall and spring to reinforce and extend the learning that began in the summer. Topics for the follow-up conferences were selected based on the needs of the teachers, which were self-assessed by teachers and discussed among the project leadership.

The final component of the professional development was comprised of monthly site visits from instructional coaches. Two experienced *Core-Plus* teachers conducted the visits to identify and support teachers' needs. The NCIM coaching model, designed by the project staff, allowed the coaches to customize professional development during their visits for every NCIM teacher. The relationship between the coaches and teachers formed during the Summer Workshop when the instructional coaches acted as facilitators. When the school year started, the coaches determined and addressed the needs of each teacher. Unlike other models, there was no prescriptive framework for these interactions, and project staff and instructional coaches jointly determined a list of activities used to engage teachers.

4 Theoretical Perspectives

It is an arduous task to link a curriculum directly to student learning when other variables are confounded in the complex setting of a classroom. Teachers' beliefs and backgrounds greatly influence how they implement curricula, potentially causing the implemented curricula to be significantly different from the developers' intended curricula (Ball e Cohen, 1996; Remillard, 2000)and from a teacher's own intentions (Stein, Remillard *et al.*, 2007; Stein & Smith, 2010). It cannot be assumed that access to teachers' guides and curriculum materials will ensure curricula are being properly implemented (Scott, 1994), so it is important that claims made about curricular effectiveness include measures to judge the adequacy of implementation (Senk & Thompson, 2003; NRC, 2004).

In order to help researchers design and conduct evaluation studies, the NRC(2004) published *On Evaluating Curricular Effectiveness,* providing a framework and recommendations for those seeking to evaluate curricula. Applying some of these recommendations, the COSMIC research conducted a longitudinal comparative study to track students' learning using the *Core-Plus* materials and students using materials from the subject-specific sequence(COSMIC, 2005). They found the *Core-Plus* curriculum was positively correlated to student achievement on a reasoning test, but found no correlation between student achievement and curricular program on a standardized test or on a test of common topics to both curricular programs.

The COSMIC team has also provided methodological approaches and instruments to document and measure implementation fidelity, which measures the extent to which textbook materials are used for instruction and are not indicative of the quality of teaching (NRC, 2004; Mcnaught, Tarr *et al.*, 2008). Using Table of Contents logs, which are self reported by the teachers and customized for the textbook they were using, the COSMIC team has created a quantitative measure for how textbooks are used for instruction (Mcnaught, Tarr *et al.*, 2008). They found teachers using *Core-Plus*covered just over 60% of the textbook content. However, when teaching textbook content they rarely used supplemental sources for their instruction. The research conducted in this paper is guided by the recommendations of the NRC and the work of the COSMIC project.

5 Methods

This study utilized both qualitative and quantitative measures. First, a quasi-experimental matched group design was used, followed by an analysis to determine differences in teachers' implementation of *Core-Plus*. For teachers attending the summer workshops, 2009-2010 student test data from schools implementing *Core-Plus* was contrasted with test data from comparison schools using subject-specific curricular. Following recommendations from the NRC (2004), students were not used as the unit of analysis because they are nested within groups and do not experience the curricula as an individual. Hierarchical linear modeling (Raudenbush & Bryk, 2002) was utilized to model variation in student achievement since randomization of students was impractical. Using student, teacher, and school level data, three-level models were used with students nested within teachers and teachers nested within schools. The dependent variable was student achievement on the North Carolina EOC Algebra I and Algebra II standardized assessments. There were approximately 2,426 students in the Algebra I sample and 1,795 in the Algebra II sample, representing students from over 50 schools with more than 100 teachers. Independent student level variables included: gender, race/ethnicity, number of days present for class, and number of days absent. Independent teacher level variables included those taken from a mathematics content knowledge assessment (CKA), a background questionnaire, and a beliefs survey. School level variables included average daily membership (ADM) and the needy percent for the school (%FRL).

Next, the sample of teachers was restricted to only teachers of *Core-Plus* to analyze their curricular implementation in light of their professional development exposure. The restricted sample included four target populations, each with varying levels of NCIM experience, Group A consisted of 7 teachers from the NCIM project schools who received instructional coach visits each month following the summer workshops. Two Group F teachers had an instructional coach only and no summer support, Group B teachers (n=6) only participated in the summer workshops, and Group D teachers (n=6) were not involved in any aspect of the NCIM project.Each teacher completed a Table of Contents log to analyze their implementation, were observed teaching in their classroom (by a researcher and instructional coach), and interviewed on their instructional practices and beliefs about teaching mathematics. This data provides a detailed account of their implementation of *Core-Plus*.

6 Results: Curricular Effectiveness of Integrated Mathematics

Algebra I Student Achievement. For the workshop sample of teachers, integrated mathematics students had a mean of 157.80, 5.22 points higher than the mean for subject-specific students$(\mu_{ss} = 151.80)$ (Appendix A). Integrated mathematics students had a mean of at least four points higher than subject-specific students for every subgroup except for 11th and 12th grade students. The largest mean difference, in favor of integrated mathematics, was for Asian students at 13.80 points. There were much higher passing rates for integrated mathematics students overall (86.29% vs. 69.00% for subject-specific).

The HLM analysis showed that, on average after controlling for a variety of student, teacher, and school characteristics, integrated mathematics teachers had student results 4.45 points higher than subject-specific teachers on the Algebra I EOC exam. There were also significant differences in student achievement based on student race, student grade level, teacher content knowledge, and school need. For example, each one-point increase in teacher content knowledge resulted in a 0.05-point increase in student Algebra I achievement. Students at higher grade levels had significantly lower test scores and each day a student was absent resulted in a 0.23 drop in their Algebra I test score. On average, White students outperformed Black students by 3.58 points and Hispanic students by 2.40 points.

Further, the relationship between Algebra I score and the designation of Black significantly depended on curriculum type (Figure 2). White students in integrated mathematics tended to score 2.33 points higher than their subject-specific peers on the Algebra I EOC ($p<0.0001$). Similarly, Black integrated mathematics students outperformed their subject-specific peers by 1.38 points on the Algebra I EOC ($p=0.014$). The negative slope of the integrated mathematics line suggests that on average, White students outperform Black students by 2.19 points ($p<0.0001$). The negative slope of the subject-specific line suggests that on average, White students outperform Black students by 1.24 points ($p<0.0001$). The significant slopes showed that White students outperform Black students regardless of curricular pathway, however there is an even greater advantage to White and Black students using *Core-Plus* over subject-specific curricula.

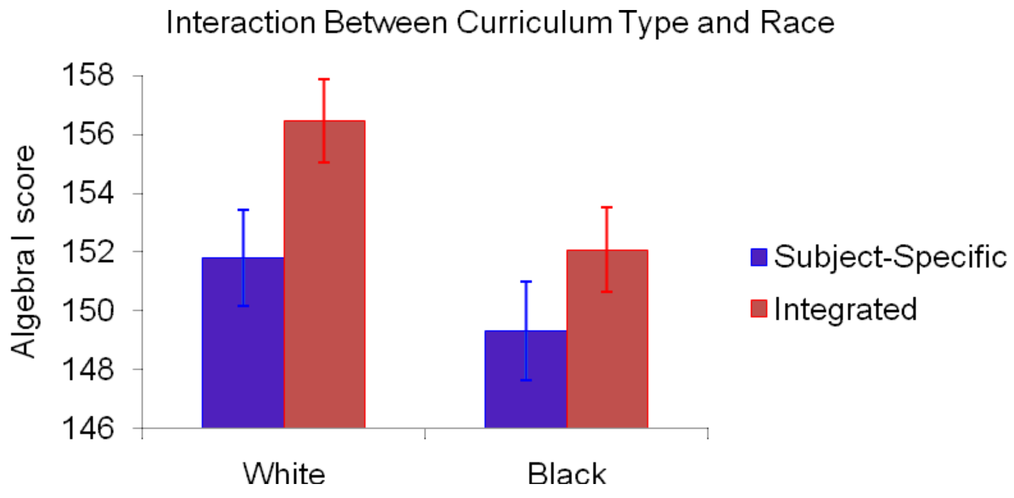

Figure 2 – Interaction Between Curriculum Type and Student Race.

Algebra II Achievement. Integrated and subject-specific mathematics students who took the Algebra II EOC had remarkably similar prior achievement scores on the Algebra I EOC, 155.35 and 155.59 respectively (Appendix B). Subject-specific students had a 2.34-point higher mean achievement on the Algebra II exam than integrated mathematics students. Further, subject-specific students had a higher mean achievement than integrated mathematics students for all subgroups except for Black students and a higher passing rate for all subgroups except for Black and Asian students (All Asian students in both pathways passed the exam).

Using HLM, there were no significant differences in student achievement based on curriculum type, and unlike the Algebra I analysis there were no significant interactions between curriculum type and race. There was a significant three-way cross-level interaction between student prior achievement, teacher content knowledge, curriculum type, and Algebra II achievement (Figure 3). For students with low Algebra I scores, teachers of integrated mathematics with high content knowledge had Algebra II EOC results that were 0.99 points higher than teachers with low content knowledge, but this result was only moderately significant ($p=0.10$). For students with high prior achievement, teachers of integrated mathematics with high content knowledge had Algebra II EOC results that were 2.54 points higher than teachers with low content knowledge ($p=0.0047$). There were no significant differences in the slopes of the lines for subject-specific teachers, nor between any of the contrasts between curriculum types. These results suggest that teachers of *Core-Plus* Course 3 with higher content knowledge have more successful student results on the Algebra II exam than teachers with lower content knowledge. As students progress to the third *Core-Plus* course, the textbook content gets more difficult, and these results showed that teacher knowledge was important to increased student achievement.Interestingly, there were no significant differences in student achievement for subject-specific teachers based on their content knowledge, suggesting that teacher content knowledge had a smaller an impact on student achievement in subject-specific classrooms.

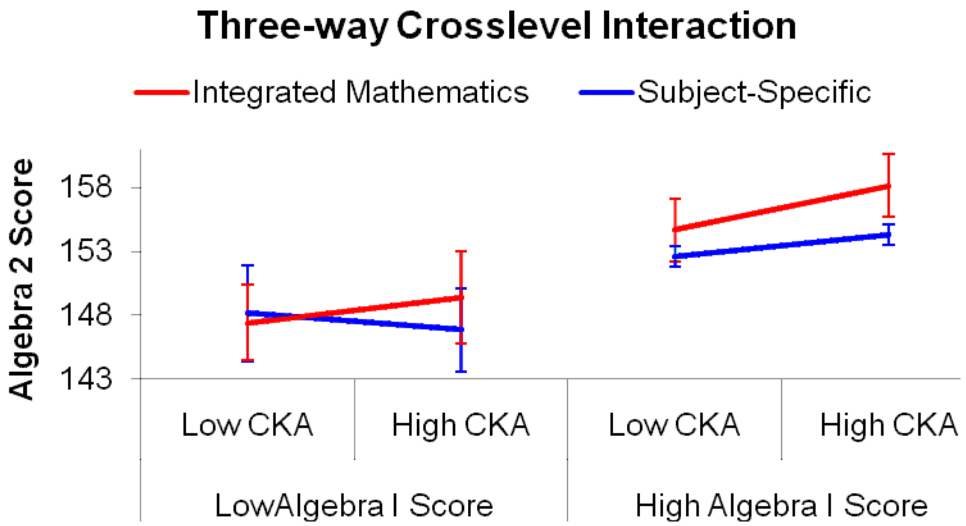

Figure 3 – Three-way Crosslevel Interaction Between Curriculum, Student Prior Achievement, and Teacher Content Knowledge.

Summary Quantitative Results. *Core-Plus* teachers had higher scores on the Algebra I EOC, while there was no difference between curricular pathways on the Algebra II EOC. A content analysis concluded that while content in *Core-Plus*was highly aligned to items on the Algebra I EOC (making it a fair test for comparing curricular results), a similar analysis showed that *Core-Plus* materials were not strongly aligned to released items on the Algebra II EOC, indicating that some of what the EOC tested was not taught in integrated math and that some of what was taught in integrated math was not tested. However, the result that integrated mathematics students experienced the same level of success as traditional Algebra II students despite the lack of alignment between test and materials could be taken to indicate that a multiple-year integrated mathematics curriculum is at least as effective as a traditional curriculum.

Teacher content knowledge was an important predictor of student achievement for both outcome measures. Regardless of student prior achievement, *Core-Plus* teachers with high content knowledge had higher student Algebra II achievement than *Core-Plus* teachers with low content knowledge. These results suggest the importance of having professional development that provides *Core-Plus* teachers with a strong mathematical background.

7 Results: Importance of Professional Development

This study found significant differences in teachers' implementation of *Core-Plus* textbook content based on their participation in the NCIM professional development. On average, just over half of the content in the textbook was covered (52.30%), though there was considerable variation among how much content each teacher taught, ranging from 27.69 to 81.71% (Table 1). Teachers who participated in the project workshops provided their students with a higher opportunity to learn textbook content than non-workshop participants. There were significant differences in the percentage of textbook taught between Groups B and F and Groups A and F ($\alpha=0.05$). These data suggest the importance of workshop attendance on textbook implementation. The two teachers who were provided with an instructional coach, absent workshop attendance, had significantly lower textbook implementation.

Table 1– Mean (and Standard Deviations) of the Implementation Indices

	Percent of Textbook Content Taught Through *Core-Plus* or Supplements	Of the Content Taught, Weighted Percent of How the Textbook & Supplements Were Used
Group A (All NCIM parts)	56.19 (14.31)	90.65 (8.32)
Group B (Workshops only)	58.79 (9.90)	98.48 (3.83)
Group D (No NCIM exposure)	46.67 (9.74)	70.58 (17.99)
Group F (Coaches only)	33.80 (6.30)	77.98 (17.14)
Entire Sample	52.30 (13.93)	87.29 (14.94)

There were also differences between groups in how they used their textbook for instruction. For example, when Group B teachers taught content in the textbook, they were directly using the textbook for their instruction instead of supplements (Table 1- column 2). Group D teachers used alternative sources for instruction more frequently than teachers who took part facets of the NCIM project. Groups with teachers attending the summer workshops (A and B) rarely used alternative sources for instruction and utilized the textbook as the primary resource in their instruction.

The analysis of textbook implementation showed significant differences between teachers that attended the NCIM workshop and those that had not. This suggests that workshop attendance can increase teachers' trust for the curriculum or knowledge about how to implement it with students. Next, teacher interviews and observations were analyzed to try to determine why there were differences in teacher implementation based on professional development exposure.

Qualitative data indicated that teachers' beliefs about how students learn mathematics, their trust for the curriculum, and systemic factors influenced decisions teachers made about textbook implementation. Teacher beliefs about how students learn mathematics had an impact on teachers' use of collaborative groups, supplements they provided to students, and their ability to let students struggle through mathematics. Teachers' trust for the curriculum was a barometer for how frequently they utilized reform or traditional instructional practices. Participation at the NCIM summer workshop helped Group A and B teachers feel more confident and trusting of the *Core-Plus* curriculum and instructional practices, and the instructional coaches supported these ideas throughout the year for Group A teachers. Systemic factors within a school or system also had an impact on teachers' implementation of *Core-Plus.* The constraints and affordances of the system (access to materials, scheduling, and student adjustment to *Core-Plus*)contributed to the variance among teachers' implementation of the textbook materials.

8 Final Considerations

This research offers insight into the differences in student achievement for students learning with and without the *Core-Plus* materials. Further, it provides an account of the impact different student, teacher, and school traits have on student learning in *Core-Plus* classrooms and the influence professional development plays on teachers' curricular implementation. Results from this study demonstrate that teachers using *Core-Plus* need professional development designed to strengthen their mathematical content knowledge and reform-based instructional practices. Findings suggest encouraging results for the use of integrated mathematics with typically underserved student populations and among teachers who were provided with sustainable support following an authentic workshop experience. As teachers navigate the transition between different curricula and standards, it is imperative researchers understand how professional development offerings effect instruction so that high-quality, targeted professional development can be designed and implemented to meet teachers needs. Findings from this research will help guide future professional development offerings, policy decisions, and help strengthen mathematics education.

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Appendix A. Algebra I EOC Means and Passing Rates for Students Within Each Subgroup

		Grand Mean	**Grade Level**					**Gender**	
			8th	9th	10th	11th	12th	Male	Female
IM	Sample Size (n)	569	-	375	181	12	1	222	347
	Mean	157.80	-	159.69	154.86	145.42	135.00	157.15	158.22
	Standard Dev.	9.63	-	9.10	9.49	5.18	0.00	10.13	9.30
	Passing Rate	86.29%	-	91.73%	77.90%	50.00%	0.00%	84.68%	87.32%
SS	Sample Size (n)	1942	61	1463	306	89	23	960	982
	Mean	151.58	151.77	153.03	146.68	145.70	146.61	151.25	151.90
	Standard Dev.	8.53	9.00	8.29	7.53	6.24	7.31	8.98	8.06
	Passing Rate	69.00%	70.49%	75.73%	47.06%	38.20%	47.83%	67.81%	70.16%
Entire Sample	Mean	152.99	151.77	154.39	149.72	145.66	146.13	152.36	153.55
	Standard Dev.	9.17	9.00	8.87	9.20	6.10	7.53	9.49	8.84

		Race						**Attendance**	
		AmIn	Asian	Hispanic	Black	White	Multi	Absent ≤ 20 Days	Absent > 20 Days
IM	Sample Size (n)	10	41	68	171	261	18	548	21
	Mean	154.20	165.93	157.97	154.19	159.10	156.22	158.13	149.43
	Standard Dev.	8.42	7.42	10.44	8.65	9.50	7.19	9.54	8.27
	Passing Rate	80.00%	100.00%	88.24%	77.19%	90.04%	83.33%	87.23%	61.90%
SS	Sample Size (n)	51	24	157	717	944	49	1800	142
	Mean	147.73	152.13	150.68	148.97	153.87	152.24	152.06	145.53
	Standard Dev.	7.92	8.38	7.92	8.55	7.95	9.15	8.37	8.33
	Passing Rate	56.86%	79.17%	65.61%	56.49%	79.34%	71.43%	70.89%	45.07%
Entire Sample	Mean	148.79	160.83	152.88	149.98	155.00	153.31	153.47	146.03
	Standard Dev.	8.29	10.23	9.36	8.81	8.58	8.79	9.03	8.40

Appendix B. Algebra II EOC Means and Passing Rates for Students Within Each Subgroup

		Grand Mean	**Grade Level**					**Gender**	
			8th	9th	10th	11th	12th	Male	Female
IM	Sample Size (n)	290	-	12	142	130	6	123	167
	Mean	148.83	-	152.67	150.64	146.94	139.33	148.77	148.87
	Standard Dev.	7.12	-	4.58	6.91	6.77	5.43	7.04	7.20
	Passing Rate	58.28%	-	83.33%	69.72%	45.38%	16.67%	56.91%	59.28%
SS	Sample Size (n)	1612	-	265	719	560	68	695	917
	Mean	151.17	-	154.74	152.59	148.25	146.31	150.71	151.52
	Standard Dev.	8.44	-	7.91	8.58	7.45	6.71	8.29	8.54
	Passing Rate	67.80%	-	83.40%	73.85%	55.89%	41.18%	65.76%	69.36%
Entire Sample	Mean	150.81		154.65	152.27	148.00	145.74	150.42	151.11
	Standard Dev.	8.29	-	7.80	8.35	7.34	6.86	8.14	8.40

		Race						**Attendance**	
		AmIn	Asian	Hispanic	Black	White	Multi	Absent ≤ 20 Days	Absent > 20 Days
IM	Sample Size (n)	-	3	21	178	78	10	280	10
	Mean	-	153.33	147.48	148.60	149.88	146.30	149.05	142.60
	Standard Dev.	-	3.79	7.90	6.85	7.27	9.07	7.03	7.37
	Passing Rate	-	100.00%	47.62%	57.87%	62.82%	40.00%	59.64%	20.00%
SS	Sample Size (n)	49	31	85	474	935	38	1521	91
	Mean	150.80	157.87	151.13	147.23	152.92	152.34	151.59	144.19
	Standard Dev.	8.77	5.21	7.92	8.03	8.07	7.11	8.23	8.74
	Passing Rate	67.35%	100.00%	70.59%	50.84%	74.65%	78.95%	70.09%	29.67%
Entire Sample	Mean	150.80	157.47	150.41	147.60	152.69	151.08	151.20	144.03
	Standard Dev.	8.77	5.22	8.01	7.74	8.05	7.85	8.11	8.60