The Relationship between High School Mathematics Curriculum and Mathematics Course-Taking and Achievement for Students Attending Community College

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Studying the impact of high school mathematics curricula on postsecondary mathematics course-taking and achievement is motivated by two related objectives. First, there is a need to better understand the mathematics preparation of an increasingly diverse group of students planning to enroll in a postsecondary institution (National Center for Education Statistics [NCES], 2014; Programme for International Student Assessment [PISA], 2012). Second is the importance of establishing an empirical research base characterizing the efficacy of high school mathematics curricula in pursuit of the common goal of having more students learn more mathematics more effectively.

Common to meeting these objectives is developing a deeper understanding of the key features of a student’s high school mathematics preparation. We focus on the high school mathematics curriculum a student completed, which is widely viewed as an important component of a student’s success in postsecondary mathematics (Augustine, 2007; Mathematical Sciences Education Board [MSEB], 2004; National Research Council [NRC], 2002). However, calls for additional research to better understand the impact of high school mathematics curricula on students’ college mathematics performance (MSEB, 2004; NRC, 2002; NCES, 2006) means that there is a need to more thoroughly document the preparation of students for postsecondary mathematics.

We focus on understanding the mathematics preparation of students who enroll in a community college for three overlapping reasons. First, approximately 41% of first-time students in postsecondary education enroll in community colleges (NCES, 2014). Moreover, enrollment in community colleges has recently risen while enrollment in four-year institutions has remained steady. As of October 2008, approximately 3.4 million young adults (aged 18–24) in the U.S. were enrolled in community colleges, an increase from 3.1 million the previous year (Pew Research Center, 2009). Thus, community college students represent a large and growing population of students.

Second, community colleges provide an important educational access point to four-year schools, and ensuring that these students have adequate mathematics preparation can be central to students’ successfully transferring to a four-year school after satisfactorily completing coursework at a community college. Many students who plan to earn a bachelor’s degree opt to begin their postsecondary study in a community college, sometimes because they need additional coursework before being able to enroll at a four-year school, sometimes for financial, family, or job-related reasons, and sometimes because it’s simply more convenient (Alfonso, 2006; Bailey & Averianova, 1998). The fact that community colleges have, historically, had proportionally higher enrollments of non-White and low-income students compared to four-year schools also speaks to the access issue (Bahr, 2008). Relatedly, students attending community college typically require more developmental coursework in mathematics than their counterparts in four-year schools (Adelman, 2004; Minnesota State Colleges and Universities, 2011; NCES, 2003), highlighting the importance of understanding their preparation for postsecondary mathematics.

Third, many students earn a terminal degree at a community college and understanding the mathematics preparation of this group of students as a function of the high school mathematics curriculum they completed is important. These students are especially likely to need to complete developmental mathematics courses as part of satisfying institutional mathematics requirements (Alfonso, Bailey, & Scott, 2005). A better understanding of the impact of high school mathematics curriculum may provide important information for institutions seeking to better support the mathematics learning of these students.
Theoretical Framework

High School Mathematics Curricula

There are three general categories of high school mathematics curricula. The most widely used mathematics curricula in the nation’s high schools are referred to here as commercially developed (CD) or traditional curricula that stress traditional algorithms and procedures (Schoenfeld, 2004). These curricula tend to be teacher-centered, limit the role of technology, and discourage group work (Roitman, 1999; Schoenfeld, 2004). Available evidence suggests that a theoretical model incorporating research findings on student learning has not guided the development of CD curricula (Willoughby, 2010).

National Science Foundation-funded (NSF-funded) curricula represent a second category of curricula. These curricula were funded through a solicitation of proposals through the National Science Foundation in the early 1990s (RFP NSF 91-100) and were designed to be aligned with the National Council of Teachers of Mathematics’ (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989). The mathematics curricula funded by NSF included *Contemporary Mathematics in Context* (CMIC or Core-Plus) (Coxford, Fey, Hirsch, Schoen, Burrill, Hart, & Watkins, 1998), *Interactive Mathematics Program* (IMP) (Fendel, Resnick, Alper, & Fraser, 1998), and *Mathematics: Modeling Our World* (MMOW or ARISE) (Garfunkel, Godbold, & Pollak, 1998). A theme of these curricula is their integration of topics in algebra, geometry, probability, statistics and discrete mathematics, their deemphasizing of algorithmic manipulation, and their emphasis on the role of students as active participants in learning that is motivated by real world questions and relies heavily on small groups (Schoenfeld, 2004). Available evidence suggests that the development of NSF-funded curricula has been guided by, but not dictated by, theoretical models incorporating research findings on student learning (Post et al., 2010).

Another category of curriculum is represented by the University of Chicago School Mathematics Project (Usiskin, 1986) curriculum, which was initially developed in 1983 and combines features of NSF-funded and CD curricula (Hirschhorn, 1993; Schoenfeld, 2004; Thompson & Senk, 2001). The UCSMP curriculum has received funding from private sources (AMOCO) as well as NSF support. It is best known through the algebra, geometry, algebra II, functions, statistics, trigonometry, precalculus and discrete mathematics texts that emphasize reading, problem solving, typical or everyday applications of mathematics, and the use of technology including calculators and computers. The ongoing development of the UCSMP curriculum has in large part been informed by a theoretical model that incorporates research findings on student learning.

The Impact of High School Mathematics Curricula on Postsecondary Mathematics Achievement

Research examining the impact of high school mathematics curricula on students’ postsecondary mathematics achievement has only recently begun to appear in the literature. The focus on NSF-funded curricula in this research is in part a response to intense criticism of these curricula (Schoenfeld, 2004). The essence of the criticism is that NSF-funded curricula do a poor job of preparing students to succeed in postsecondary mathematics, especially calculus (Klein, 2000; Wu, 1997). However, there is no credible empirical evidence that we could find supporting this criticism for students enrolled in four-year institutions and none for students enrolled in community colleges.

For four-year schools, Schoen and Hirsch (2003) reported that students completing the NSF-funded Core-Plus curriculum had on average higher grades in calculus I and other more advanced mathematics courses compared to students completing a CD curriculum. Hill and Parker (2006) reported that students who completed Core-Plus in high school began their college mathematics coursework with less difficult courses and subsequently completed even less difficult mathematics courses than students who completed a different mathematics curriculum in high school. However, their findings were severely compromised by the fact that often the high school mathematics curriculum students completed could not be determined. Harwell et al. (2009) found no relationship between curriculum and the grade earned in a student’s first college mathematics course for a sample of students enrolled in a single large public institution, but did find that students who completed a NSF-funded curriculum tended to enroll in less difficult courses than students who completed a CD curriculum in high school.

For community colleges, Bahr (2007) found evidence of multiple academic deficiencies for freshmen including inadequate mathematics preparation and described their negative impact on postsecondary success. Specifically, Bahr reported that only 28% of community college students who began their college mathematics course-taking with a developmental course went on to successfully complete a nondevelopmental mathematics course. Adelman (2006) reported a strong relationship between completion of four years of high school mathematics culminating in a college algebra course in high school and success in college, a finding also reported for community college students by Bettinger and Long (2005), Fong, Huang, and Goel (2008), and Stern and Pavelchek (2006).

However, there is apparently no research examining the role of specific high school mathematics curricula on students’ mathematics performance in community colleges. To better understand this relationship we posed the following questions.
Research questions

1. Do students who completed at least three years of high school mathematics in a NSF-funded curriculum differ from those who had similar exposure to a CD or UCSMP curriculum in the difficulty level of their first college mathematics course or in the grade they earned in that course, when taking into account background factors such as prior mathematics achievement, ethnicity, and sex?

2. Does this relationship vary across a sample of two-year community colleges?

We chose the grade a student earned in their first college mathematics course and the difficulty level of that course as the outcomes of interest because the majority of students (54.2%) in our sample only completed a single course in mathematics in community college (29.9% completed two courses, 15.9% completed three or more courses).

Method

Research Design

A retrospective cohort (quasiexperimental) design was used in which the grade students earned in their first college mathematics course, and the difficulty level of that course, served as outcome variables. The grade data were analyzed separately for students who began community college with a developmental mathematics course and those who began with a nondevelopmental mathematics course (e.g., college algebra). In addition, we analyzed the grade data separately for students who completed two or more courses in mathematics. This approach is consistent with Pedhazur and Schmelkin’s (1991) elimination strategy, in which a covariate is converted to a constant and enhances the credibility of inferences. Based on their high school mathematics curriculum students were categorized into one of three curriculum cohorts: NSF-funded, CD, or UCSMP. To identify students’ high school mathematics curriculum, we contacted each of the 290 high schools represented in our sample and obtained descriptions of their mathematics programs, including the mathematics courses offered and the mathematics textbooks used during the period the students were in high school (1998–2002). For approximately 25% of students, the high school they attended used more than one curriculum, which required cataloguing the high school mathematics courses that appeared on the transcripts of these students and combining this with collateral information obtained from the high schools to assign these students to a curriculum cohort.

We combined the NSF-funded curricula (Core-Plus, IMP, MMOW) in the analyses for two reasons. First, there are strong conceptual links among these curricula including their adherence to a common set of standards in their construction that features (i) contextually oriented mathematics in which problems emanate from real world situations (voting, environment, change over time etc.) (ii) the use of cooperative group solutions to problems and student-centered investigations (iii) wide-scale use of technology, student-centered investigations and (iv) a focus on algebra, geometry, probability, and statistics each year (NCTM, 1989). Second, we found no important differences among students completing the Core-Plus, IMP, and MMOW curricula on high school variables including ACT mathematics score, high school mathematics GPA, and years of high school mathematics, and, separately, on college variables including first college mathematics course grade, college mathematics GPA, and number of college mathematics courses completed. Thus we did not distinguish among individual NSF-funded curricula in our analyses.

Population and Sample

The sampled populations consist of 3,197 students who enrolled in 21 two-year community colleges in the upper Midwest of the U.S. All 21 institutions are part of a state colleges and universities system in a single state. The institutions sampled here include three state colleges, eight community colleges, eight community and technical colleges, one technical college and one tribal and community college. Fifteen of the institutions are located in rural settings, five in suburban settings, and one in an urban setting. These institutions all have an open enrollment policy.

All students in our sample completed at least three levels (years) of high school mathematics in a CD, NSF-funded, or UCSMP curriculum, and completed at least one postsecondary mathematics course. Also, all students enrolled in a community college in fall 2002 or fall 2003 immediately after graduating from high school. The requirement that students had to have completed at least three years of high school mathematics helped to ensure sufficient exposure to a curriculum for its effects to appear. However, this requirement also makes it likely that our target population of students is on average more academically proficient than would be the case for a broader population of community college students.

Variables

Variables in our student data included the type of high school mathematics curriculum (CD, NSF-funded, UCSMP), which was coded so that the CD curriculum was the reference group, various measures of students’ prior mathematics achievement (e.g., high school mathematics GPA, ACT mathematics score), grade earned in the first college mathematics course (0.0–4.0 scale), and demographic information (e.g., ethnicity and sex).
The difficulty of each mathematics course at each institution was categorized into one of four difficulty levels based on course descriptions:

**Level 1:** Courses that should have been completed at the high school level and generally do not earn college credit. Students entering college without the required or recommended high school background are directed to these courses, which are designed to provide a foundation for students to be successful in future mathematics courses. This is the level we consider to be remedial or developmental.

**Level 2:** Courses that a student who satisfactorily completed four levels (years) of mathematics in high school would not repeat in a college setting (e.g., college algebra, precalculus mathematics).

**Level 3:** Beginning calculus.

**Level 4:** Courses whose difficulty is consistent with that of calculus II or higher (e.g., differential equations, college geometry, calculus II).

These levels are similar to those used in Teitlebaum’s analysis of high school mathematics course-taking using the National Educational Longitudinal Study data.

**Data Analyses**
Initially descriptive analyses were performed to explore patterns in the data. These were followed by two-level hierarchical linear modeling (HLM) (Raudenbush & Bryk, 2002), which treated students as nested within community colleges. To control for compounding of Type I error rates we used an adjusted Type I error rate attributed to Sidak (1967) of the form $\alpha' = 1 - (1 - \alpha)^{1/k}$, where $\alpha$ is the unadjusted Type I error rate, $k =$ number of statistical tests, and $\alpha'$ is the adjusted Type I error rate. We chose to compute adjusted Type I error rates for each table of statistical test results we report based on an overall $\alpha = 0.10$, which resembles a family-wise error rate strategy often associated with planned comparisons in ANOVA.

**Results**

**Descriptive Analyses**
Among the sampled community colleges the average enrollment (full time + part time) was 2,038.31 ($SD = 941.23$), and the average mean ACT mathematics score was 20.64 ($SD = 0.97$). Summaries for number of years of high school mathematics completed, high school mathematics GPA, ACT mathematics score, grade in first college mathematics course, and the difficulty level of that course by high school mathematics curriculum across institutions are reported in Table 1.

The variance in a dependent variable explained by an independent variable was used as an index of effect size for the relationships in Table 1, with larger effects associated with stronger relationships. On the whole, effect sizes comparing the NSF-funded and UCSMP cohorts, and the NSF-funded and CD cohorts, uniformly favored the UCSMP and CD cohorts with most effect sizes in the moderate range (Cohen, 1988). For example, the effect size for ACT mathematics scores as the outcome between the NSF-funded versus UCSMP curriculum cohorts was 0.27, meaning that 27% of the variance in ACT mathematics scores was explained by whether students completed an NSF-funded or UCSMP high school curriculum.

| Table 1. Descriptive Statistics by High School Mathematics Curriculum | HS Mathematics Curriculum |
|---|---|---|---|
| | Commercially Developed | UCSMP | NSF-funded |
| | $M$ | $SD$ | $n$ | $M$ | $SD$ | $n$ | $M$ | $SD$ | $n$ |
| Yrs. HS mathematics completed | 3.55 | 0.66 | 1622 | 3.72 | 0.63 | 440 | 3.55 | 0.62 | 422 |
| HS mathematics GPA | 2.68 | 0.75 | 1618 | 2.74 | 0.74 | 439 | 2.77 | 0.75 | 419 |
| ACT mathematics score | 21.05 | 4.03 | 662 | 21.63 | 3.94 | 235 | 20.58 | 3.87 | 163 |
| Grade in first college mathematics course | 2.64 | 1.16 | 1535 | 2.59 | 1.18 | 417 | 2.6 | 1.11 | 393 |
| Difficulty level of first college math course | 1.64 | 0.7 | 1622 | 1.69 | 0.74 | 440 | 1.47 | 0.59 | 422 |

Note: Difficulty level 1 = course that should have been completed in high school, 2 = college algebra, 3 = Calculus I, 4 = Calculus II or a more difficult course.
mathematics curriculum (examination of the means showed that NSF-funded students scored on average lower); for NSF-funded versus CD students this effect size was 0.12 favoring CD students.

Descriptive statistics for students by the number of years of high school mathematics completed are reported in Table 2. Of the students sampled, 52.4% (1,658) completed three years of high school mathematics, 39.2% (1,241) completed four years of high school mathematics and the remaining 8.4% (266) completed a fifth year (typically calculus) of high school mathematics. As can be seen in Table 2, the percentage of students who initially enrolled in a developmental mathematics course in college was 55.8%, 40.0%, and 12.4% for students who completed 3, 4, or 5 years of high school mathematics, respectively. The mean (standard deviation) grade earned in students’ first college mathematics course was 2.54 (1.14), 2.67 (1.17), and 2.79 (1.16) for students who completed 3, 4, or 5 years of high school mathematics, respectively.

Summary statistics for students for high school mathematics curriculum, gender, and ethnicity by the institution location variable are reported in Table 3. As can be seen, more NSF-funded students (38%) attended urban/suburban institutions than CD students (29%). This is likely the case because the NSF-funded curriculum were predominantly implemented in urban and suburban high schools and these students disproportionately went on to attend urban and suburban community colleges. African American, Hispanic, and Asian students predominantly enrolled in urban and suburban institutions whereas nearly 98% of the students attending rural institutions were Caucasian.

### Inferential Analyses

#### Difficulty level of the first mathematics course

First an unconditional hierarchical generalized linear model (HGLM) was fitted to the binary difficulty outcome ($1 = \text{started community college with college algebra or a more difficult course, } 0 = \text{started community college with a developmental mathematics course}$). The average (across institutions) log-odds of a student beginning with college algebra or more difficult course as opposed to a developmental mathematics course was 0.24. This means that for a typical institution (i.e., with a random effect of 0), the odds of a student taking a first mathematics course of difficulty level 2 or greater relative to taking a developmental course were $e^{0.24} = 1.27$, which corresponds to a model probability that a randomly selected student would begin with a course of difficulty level 2 or higher of $\frac{e^{0.24}}{1 + e^{0.24}} = 0.56$.

The results for the conditional HGLM (see Table 4) revealed that the type of high school mathematics curriculum a student completed was unrelated to the likelihood of students beginning their mathematics coursework at difficulty level 2 or higher.

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### Table 2. Course Difficulty Level by Years of High School Mathematics Completed

<table>
<thead>
<tr>
<th>Years of High School Mathematics Completed</th>
<th>3 years</th>
<th>4 years</th>
<th>5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>%</td>
<td>$n$</td>
</tr>
<tr>
<td>Difficulty level of first college math course</td>
<td>1 925 55.8</td>
<td>497 40</td>
<td>33 12.4</td>
</tr>
<tr>
<td>Difficulty level of last college math course</td>
<td>1 440 26.5</td>
<td>193 15.6</td>
<td>14 5.3</td>
</tr>
</tbody>
</table>

Note: Difficulty level 1 = course that should have been completed in high school, 2 = college algebra, 3 = Calculus I, 4 = Calculus II or a more difficult course.
higher, which means that the difficulty level of students’ first course is unrelated to the high school mathematics curriculum they received. ACT mathematics score, high school mathematics GPA, and years of high school mathematics were the only statistically significant predictors of the likelihood a student would begin their mathematics coursework with a course of difficulty level 2 or higher.

**Grade earned in the first mathematics course**

To analyze the grade data four models were fitted, one for students who began their community college mathematics coursework with a developmental course (i.e., difficulty level 1) and another for students who began their community college mathematics coursework with college algebra or a more difficult course (i.e., difficulty level $\geq 2$). In addition, the same two models described previously were fitted to the subsample of students who completed two or more mathematics courses in community college. An initial analysis showed that there was enough variation in average grades between community colleges to continue modeling ($f_{\text{log}} = 0.05, \rho_{\text{intraclass}} = 0.03$). Next, we constructed a predictive model to account for the variation in grades. The results of this analysis for all students who began their community college mathematics coursework with a developmental course are presented in Table 5.

These results indicate that the type of high school mathematics curriculum a student completed was unrelated to the grade earned in the first course. In contrast, both ACT

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**Table 3. Descriptive Statistics by Community College Location**

<table>
<thead>
<tr>
<th></th>
<th>Community College Location</th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rural</td>
<td>Urban/Suburban</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$n$</td>
<td>Row %</td>
<td>Column %</td>
<td>$n$</td>
<td>Row %</td>
<td>Column %</td>
</tr>
<tr>
<td>Curriculum</td>
<td>Commercially Developed</td>
<td>1147</td>
<td>70.7</td>
<td>67.4</td>
<td>475</td>
<td>29.3</td>
</tr>
<tr>
<td></td>
<td>UCSMP</td>
<td>295</td>
<td>67</td>
<td>17.3</td>
<td>145</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>NSF-Funded</td>
<td>261</td>
<td>61.8</td>
<td>15.3</td>
<td>161</td>
<td>38.2</td>
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<tr>
<td>Gender</td>
<td>Female</td>
<td>984</td>
<td>70.2</td>
<td>42.5</td>
<td>418</td>
<td>29.8</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>1331</td>
<td>76.2</td>
<td>57.5</td>
<td>416</td>
<td>23.8</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Asian</td>
<td>22</td>
<td>21.6</td>
<td>1</td>
<td>80</td>
<td>78.4</td>
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<tr>
<td></td>
<td>African American</td>
<td>19</td>
<td>43.2</td>
<td>0.9</td>
<td>25</td>
<td>56.8</td>
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<tr>
<td></td>
<td>Hispanic</td>
<td>8</td>
<td>40</td>
<td>0.4</td>
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<td>60</td>
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<tr>
<td></td>
<td>Caucasian</td>
<td>2121</td>
<td>76.9</td>
<td>97.7</td>
<td>638</td>
<td>23.1</td>
</tr>
</tbody>
</table>

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**Table 4. Multilevel Results for Difficulty Level Outcome**

<table>
<thead>
<tr>
<th>Effect</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>$-6.17$</td>
<td>$0.641$</td>
<td>$-9.62^*$</td>
</tr>
<tr>
<td>ACT math score</td>
<td>$0.23$</td>
<td>$0.024$</td>
<td>$9.51^*$</td>
</tr>
<tr>
<td>HS math GPA</td>
<td>$0.30$</td>
<td>$0.110$</td>
<td>$2.77^*$</td>
</tr>
<tr>
<td>Years of HS math completed</td>
<td>$0.38$</td>
<td>$0.129$</td>
<td>$2.95^*$</td>
</tr>
<tr>
<td>African American</td>
<td>$1.35$</td>
<td>$1.419$</td>
<td>$0.95$</td>
</tr>
<tr>
<td>Asian</td>
<td>$-0.59$</td>
<td>$0.412$</td>
<td>$-1.42$</td>
</tr>
<tr>
<td>Hispanic</td>
<td>$-0.97$</td>
<td>$1.045$</td>
<td>$-0.93$</td>
</tr>
<tr>
<td>Gender</td>
<td>$-0.16$</td>
<td>$0.150$</td>
<td>$-1.06$</td>
</tr>
<tr>
<td>Location</td>
<td>$-1.05$</td>
<td>$0.668$</td>
<td>$-1.57$</td>
</tr>
<tr>
<td>NSF-funded</td>
<td>$-0.17$</td>
<td>$0.226$</td>
<td>$-0.74$</td>
</tr>
<tr>
<td>UCSMP</td>
<td>$0.04$</td>
<td>$0.201$</td>
<td>$0.20$</td>
</tr>
</tbody>
</table>

Note: Difficulty level 1 = course that should have been completed in high school, 2 = college algebra, 3 = Calculus I, 4 = Calculus II or a more difficult course. $^*$ = statistically significant.
mathematics score ($\beta = 0.04$) and high school mathematics GPA ($\beta = 0.39$) were significant predictors of the grades students’ earned in their first college mathematics course (in this case a developmental mathematics course). Students with higher ACT mathematics scores and higher high school mathematics GPAs tended to earn higher grades in their first mathematics course compared to students with weaker prior mathematics achievement. Finally, gender ($\beta = -0.31$) was a significant predictor with male students on average earning lower grades than their female peers. The results indicated a similar pattern of results for subsample students who began community college with a developmental mathematics course but went on to complete two or more courses in college.

Next we examined the sample of students who began community college with a nondevelopmental mathematics course (difficulty level $\geq 2$). The results of this analysis for all students who began their community college mathematics coursework with college algebra or a more difficult course are presented in Table 6. These results show that the type of high school mathematics curriculum a student completed was unrelated to the grade earned in the first course, as were the variables capturing a student’s demographic characteristics. Both ACT mathematics score ($\beta = 0.04$) and high school mathematics GPA ($\beta = 0.55$) were significant predictors of the grades students’ earned in their first community college mathematics course. Students with higher ACT mathematics scores and higher high school mathematics GPAs tended to earn higher grades in their first university mathematics course compared to students with weaker prior mathematics achievement. Again, the results were similar for the subsample of students who began with a nondevelopmental course and completed two or more college mathematics courses.

**Discussion**

The study provides evidence of the relationship between high school mathematics curriculum and postsecondary mathematics course taking and achievement for students enrolled in community colleges. It also provides useful information for high schools and school districts interested in examining the impact of alternative high school mathematics programs on students’ subsequent college level performance. This is important for a growing and increasingly diverse population of postsecondary-bound students, but it is also important for all college-intending students. In addition, this information is helpful to the community colleges that will host these students and help them choose appropriate coursework. The lack of a significant curriculum effect suggests that there are several viable curricular approaches to adequately prepare students for college mathematics. Specifically, NSF funded high school curricula (the Connected Mathematics Project, Mathematics

Table 5. Multilevel Results for Grade Outcome for Students who began with a Developmental Course

<table>
<thead>
<tr>
<th>Effect</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.54</td>
<td>0.360</td>
<td>4.27*</td>
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<tr>
<td>ACT math score</td>
<td>0.04</td>
<td>0.016</td>
<td>2.36*</td>
</tr>
<tr>
<td>HS math GPA</td>
<td>0.39</td>
<td>0.070</td>
<td>5.52*</td>
</tr>
<tr>
<td>Years of HS math completed</td>
<td>-0.05</td>
<td>0.083</td>
<td>-0.62</td>
</tr>
<tr>
<td>African American</td>
<td>-0.26</td>
<td>0.988</td>
<td>-0.27</td>
</tr>
<tr>
<td>Asian</td>
<td>-0.31</td>
<td>0.213</td>
<td>-1.45</td>
</tr>
<tr>
<td>Hispanic</td>
<td>-0.2</td>
<td>0.492</td>
<td>-0.41</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.31</td>
<td>0.094</td>
<td>-3.27*</td>
</tr>
<tr>
<td>Location</td>
<td>-0.18</td>
<td>0.196</td>
<td>-0.92</td>
</tr>
<tr>
<td>NSF-funded</td>
<td>-0.08</td>
<td>0.133</td>
<td>-0.56</td>
</tr>
<tr>
<td>UCSMP</td>
<td>-0.25</td>
<td>0.131</td>
<td>-1.88</td>
</tr>
</tbody>
</table>

*Note: * = statistically significant.

Table 6. Multilevel Results for Grade Outcome for Students who began with a Non-Developmental Course

<table>
<thead>
<tr>
<th>Effect</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.23</td>
<td>0.311</td>
<td>0.73</td>
</tr>
<tr>
<td>ACT math score</td>
<td>0.04</td>
<td>0.013</td>
<td>2.79*</td>
</tr>
<tr>
<td>HS math GPA</td>
<td>0.55</td>
<td>0.061</td>
<td>8.93*</td>
</tr>
<tr>
<td>Years of HS math completed</td>
<td>0.06</td>
<td>0.073</td>
<td>0.79</td>
</tr>
<tr>
<td>African American</td>
<td>-0.39</td>
<td>0.593</td>
<td>-0.65</td>
</tr>
<tr>
<td>Asian</td>
<td>0.16</td>
<td>0.303</td>
<td>0.51</td>
</tr>
<tr>
<td>Hispanic</td>
<td>-1.61</td>
<td>0.729</td>
<td>-2.21</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.12</td>
<td>0.085</td>
<td>-1.34</td>
</tr>
<tr>
<td>Location</td>
<td>-0.10</td>
<td>0.146</td>
<td>-0.68</td>
</tr>
<tr>
<td>NSF-funded</td>
<td>-0.03</td>
<td>0.136</td>
<td>-0.19</td>
</tr>
<tr>
<td>UCSMP</td>
<td>-0.02</td>
<td>0.11</td>
<td>-0.16</td>
</tr>
</tbody>
</table>

*Note: * = statistically significant.
Modeling Our World and the Interactive Mathematics Project—all currently in their second editions) each developed as a full four-year curriculum option to more traditional approaches that have not adequately served all facets of the high school population. This finding is consistent with previous research conducted by the MNMAP Project that sampled students from 32 four-year postsecondary institutions (Harwell et al. 2009, 2012, 2013; Post et al., 2010). The conclusions from those studies and the present study suggest that NSF students are prepared equally well for college-level mathematics, at the four-year college level and at the community college level.

Using Hierarchical Linear Modeling (HLM), this study found that student high school ACT scores, the number of years of high school mathematics, and students’ prior mathematics performance (HS mathematics GPA) were all positive significant predictors of success in community college mathematics coursework. Suggesting, as would be expected, that more advanced mathematics course-taking and higher levels of achievement in high school is important to success in postsecondary mathematics. These findings are consistent with Adelman (2004) suggesting that four years of high school college-intending mathematics is the single most powerful predictor for students earning a college degree. Ethnicity was not found to be a significant predictor in any of the models employed, while gender was, with females achieving below that of males, suggesting the need for colleges to be sensitive to these concomitant variables when counseling students into postsecondary mathematics coursework.

Are there advantages of these NSF-funded curricula when compared to more traditional approaches? To a much greater extent students in these programs have worked in groups developing cooperative social networks that are used to support future learning. Students are expected to communicate mathematically through project reports and ongoing verbal and written assignments, to reason through complex mathematical situations over extended periods of time that are often situated in real-world contexts where students are addressing real world problems. Students are also concurrently exposed to both the procedural and conceptual aspects of mathematics with a decided focus on the latter.

The literature suggests that these generalizable skills are also listed as important for vocational success and to success in other academic content domains including, science, social science or literacy. These approaches are also more compatible with the cognitive psychological perspective as to how students are most likely effectively to learn and understand mathematics. The important point to take away from this research is that an alternate approach to high school mathematics, one that is more student-centered and based on real-world contexts, prepares students equally well for community college mathematics while providing students with opportunities to think, communicate, and reason with others in small and large group settings.

The ubiquitous goal of school mathematics is to have more students learn more mathematics more effectively. This research suggests that alternate approaches as exemplified in the NSF curricula materials, have much to offer in that regard. It also suggests that community college advising and mathematical course placement decisions would be well advised to assimilate this information into their initial student assessment protocols.

**Acknowledgments**

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**A note regarding this research**

This study is situated in the context of an NSF-funded project to provide support for high schools using NSF funded mathematics curricula. In the late1990s, the NSF funded the Minneapolis and St. Paul Merging to Achieve Standards Project (MASP)*2 housed at the University of Minnesota’s College of Education and Human Development. Professors Tom Post, Mathematics Education, and Mike Harwell, Quantitative Methods, were PIs and were supported by a variety of school personnel and graduate students. Most of these projects released their beta versions in 1998 or 1999. So, the secondary students all of whom would have completed three or four years of one of these curricula would not have graduated from high school until 2002 or 2003 and a minimum of four years later (2006 or 2007) would have graduated from a four-year institution. Community college students had a similar time trajectory but with a year or two shorter duration until graduation.

The result was a second proposal to the NSF to examine the college mathematics performance of students who had taken three or four years of these curricula while in high school. The proposal was funded circa 2006 and became known as the Minnesota Mathematics Assessment Project (MNMAP) Project. The MNMAP Project was funded by the NSF to compare the mathematical experiences (achievement, difficulty of postsecondary mathematics courses taken over time, etc.) of postsecondary students.

Critical to MNMAP was identifying the high school mathematics curricula completed by each of the students who had graduated from one of 350 Minnesota high schools and subsequently graduated from one of the 56 postsecondary...
institutions in 2007 or 2008. This information was obtained by contacting each of the 350 Minnesota high schools with students who had graduated from one of the 56 institutions. This process generated a sample of more than 20,000 students.

We argue that the value of our findings is not undermined by the time it took to obtain and analyze the data from 24 community colleges because the relationship under investigation (i.e., impact of high school mathematics curricula on a student’s mathematics achievement) continues to be relevant and important to study because states, school districts, and teachers continue to be faced with choosing a high school mathematics curriculum.

Danielle Dupuis is currently a doctoral candidate in the department of educational psychology at the University of Minnesota and research associate in test development at Pearson. Her research interests include test development, teacher effectiveness, and mathematics education.

Amanuel Medhanie received his doctorate in educational psychology from the University of Minnesota. His methodological areas of interest include the analysis of multilevel/correlated data, methods for handling missing data, and the use of propensity scores in quasiexperimental designs. In addition to providing consultation on methodological issues to a variety of institutions, he developed the statistical model used by the Minnesota Department of Education’s early indicator and response system to predict whether Minnesota students will graduate from high school on time. Medhanie is also an evaluation and testing specialist in the research, evaluation, and assessment department of Minneapolis Public Schools, where he evaluates educational programs for their impact on academic and noncognitive outcomes using a variety of quasiexperimental techniques.

Debbie Monson is an assistant professor at the University of St. Thomas in the department of teacher education. Debbie received her doctorate from the department of curriculum and instruction in mathematics education at the University of Minnesota. Her research focuses on improving secondary mathematics preservice teachers’ ability to notice and respond to student thinking as well as collaboration on the Rational Number Project work with the University of Minnesota.

Brandon LeBeau is an assistant professor in the educational measurement and statistics program at the University of Iowa, Iowa City. His research interests include longitudinal data analysis, the use of technology in the classroom, quantitative program evaluation, and applied measurement issues.
Michael Harwell is a professor of quantitative methods in the department of educational psychology at the University of Minnesota. Harwell has expertise in research design, data analysis, and measurement and has served as project statistician on multiple grants focused on school settings for the past 20 years. His research focuses on methodological issues in data analysis including developing meta-analytic effect sizes and tests; conceptual and empirical models for socioeconomic status, and research design.

Thomas Post is a professor of mathematics education and an affiliate of the STEM Education Center at the University of Minnesota. He is a founding member of the Rational Number Project. At 30 years and well over 100 publications, the RNP is the longest lasting federally funded (NSF) cooperative research project in the history of mathematics education. He is currently the co-PI of the Minnesota Mathematics Assessment Project (NSF) that has, to date, published thirteen papers, all investigating the relationship between high school mathematics curricula and subsequent college-level mathematics achievement. This article is the latest in this body of research.

References


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How Many Facebook Friends Do You Have? Mastering the Central Limit Theorem with Real Data

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The Relationship between High School Mathematics Curriculum and Mathematics Course-Taking and Achievement for Students Attending Community College

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The MathAMATYC Educator is Looking for “Lucky Larry”

Who is Lucky Larry (or Lucky Lucy)? These are examples of student work where the student arrived at the correct answer, while making one or more mistakes, or by using a flawed process. Readers are invited to send Lucky Larry submissions to the Production Manager, George Alexander, at galexander@madisoncollege.edu.