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Using student and instructor characteristics to predict student success in Algebra courses

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This paper explores the relationship between characteristics, beliefs, backgrounds and perceptions of students and instructors with students' grade earned in algebra courses at two-year post-secondary institutions in the U.S. using multiple linear regression. We present the results of an analysis of data collected during the Fall 2017 semester. From this analysis we seek to highlight a few predictor variables with significant influence on the outcome variable of student grade in the course and provide interpretations of these results.

Keywords: Algebra, grade prediction, post-secondary institutions, multiple regression analysis.

Community colleges in the US enroll 43% of all undergraduate students enrolled in two-year post-secondary institutions (Blair, Kirkman, & Maxwell, 2018). These institutions offer students the opportunity for remediation, transfer to four-year undergraduate institutions, vocational training, general education, continuing education, and worker retraining (Mesa, 2017) thus providing students of all income levels access to higher education at a minimal cost. As a result of the open access policies of community colleges, students bring a variety of backgrounds in terms of age, educational attainment, and family/work/socioeconomic status to math classrooms. To meet the needs of these students, the mathematics courses taught at a typical community college range from developmental courses (review of arithmetic and algebra courses) through courses offered during the first two years of an undergraduate mathematics major. Bahr (2010) noted the algebra courses at these colleges have failure rates ranging from 30% to 70%. Thus, there is a need to better understand factors that affect student success in these courses. Towards this end we investigate the relationship between the characteristics of instructors teaching these courses and their students' percent grade.

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Sadler and Sonner (2018) found that high school students who master coursework preparatory to calculus, including algebra, geometry and precalculus, perform well in college calculus courses. These courses are often considered a mathematical gateway to a career in science, technology, mathematics, and engineering (STEM) as well as careers in other fields. Among the topics key to future success are linear equations/functions, rational equations/functions and exponential equations/functions—topics typically taught in Intermediate Algebra (IA) and College Algebra (CA) courses at community colleges. These courses are designed for US students who desire to enter a STEM or Business-related field but have inadequate mathematical preparation. In the US, high school graduation requirements vary by state and a student entering a community college may not have had the opportunity to take a course equivalent to IA or CA in high school. In fact, the majority of high school students do not take any mathematics beyond a 9th grade algebra course (Champion & Mesa, 2018), a course preparatory to IA. Thus, a student who enrolls in IA or CA either never took the opportunity to complete the work in high school or may have taken one or both of these courses in high school but did not achieve a sufficient level of proficiency to advance. For these reasons, the IA and/or CA courses are unintentional gatekeeper courses for many community college students; hence, our desire to better understand what factors lead to student success.

Algebra Instruction at Community Colleges: An Exploration of its Relationship with Student Success (AI@CC) is a National Science Foundation funded collaborative project (Watkins et al., 2016) investigating faculty who teach IA or CA at one of the eight participating community colleges which represent three different regions of the US (Southwest, Plains and Great Lakes). Although topics contained in an IA or a CA course may vary across the participating colleges, our analyses showed a significant intersection of topics within each type of course and across the colleges. Thus, our study focused on instruction around the topics within this intersection.

In this observational study we attend to the following three elements: (1) the faculty (who they are, what they believe, what they say, and what they do for planning, enacting, and assessing instruction); (2) the students (who they are, what they believe, what they learn, and how they perceive the instruction they receive), and (3) the content (its richness, how it is organized and presented). Learning in the *AI@CC* study is operationalized as student knowledge at the conclusion of an algebra course, which may be measured by initial tests and final tests, letter grade in the course, and/or their Pass/Fail status. In this paper we share our findings about the relationships between a community college student's knowledge of algebra at the conclusion of a course as measured by course grade, represented by the percentage earned by a student in their community college algebra course, with substantively meaningful student-level and instructor-level variables.

Methods

Drawing from knowledge generated in K-12 and four-year undergraduate institutions, the *AI@CC* study endeavored to measure variables associated with student learning and performance. Instruments used by the project include the Algebra Precalculus Concept Readiness–Community College (APCR-CC) inventory (Peralta et al., under review), a student beliefs survey (Kloosterman & Stage, 1992), patterns of adaptive learning scales (PALS) survey (Midgely et al., 2000) and

teacher behavior inventory (TBI, Murray, 1987; Murray & Renaud, 1995). The psychometric properties of the instruments and the measures resulting from them have been validated (Peralta et al., under review; Peralta, 2017). Additionally, demographic information about students and instructors, students' self-reported current GPA, and their course grade as both a letter grade and a percentage were collected. We present the results of a model that uses instructor and student level characteristics as predictor variables for course grade (see Figure 1).

This model posits the existence of predictive variables at student and instructor levels that help explain the variation in student learning and performance in the algebra courses. The student-level variables include personal characteristics, APCR-CC final score, and perceptions of self. Instructor level variables include personal characteristics, behavior, knowledge and attitudes towards innovative teaching practices, knowledge of algebra for teaching and beliefs about mathematics.

Predictor Variables:

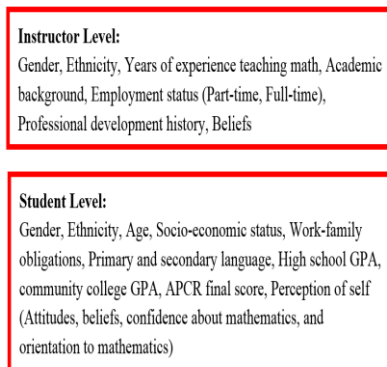


Figure 1: The AI@CC model for course grade

Measures

APCR-CC Initial and Final Scores. This 25-item assessment, measuring a single construct called quantitative reasoning (Peralta, et. al., under review), was created to measure readiness for college-level algebra and precalculus courses. The APCR-CC was administered to students twice in each of the courses observed (IA and CA). Identical versions of the test were administered at the beginning of the Fall 2017 semester (APCR-CC Initial Score) and at the end of the semester (APCR-CC Final Score). Each student's total score was determined by the sum of correct responses (one score per task) for a maximum score of 25.

Student Beliefs. The student beliefs survey was created from a survey related to motivation and achievement in the context of problem-solving following work by Kloosterman and Stage (1992). The survey, given at the beginning of the semester, had 36 items measuring personal beliefs. Of the instruments' six beliefs: (1) I can solve time-consuming problems, (2) There are word problems that cannot be solved with simple, step-by-step set procedures, (3) Understanding concepts is important in mathematics, (4) Effort can increase mathematical ability, (5) Word problems are important in mathematics, and (6) Mathematics is useful in daily life, the last two constructs were excluded from the analysis because of their low reliability (Peralta & Kohli, 2017). The score for each construct is calculated as the sum of the scores on the individual items.

Patterns of Adaptive Learning Scales. The Patterns of Adaptive Learning Scales (PALS) survey, given mid-semester, has 49 items (Midgley et al., 2000) that "are used to investigate the relation between a learning environment and a student's motivation, affect, and behavior" (Statistics Solutions, 2017). Of the instruments' nine constructs, the predictive model explored here used the

three constructs: Academic Self-Efficacy, Student Performance and Teacher Mastery. The score for each construct is calculated as the sum of the scores on the individual items.

Instructor Level Variables. Demographic variables at the instructor level including gender, full-time or part-time employment status, and years of mathematics teaching experience. Continuous variables describing the amount of formal math specific professional development, formal non-math specific professional development, and informal professional development were also included. In addition, we incorporated instructional practices, instructor beliefs and instructor knowledge of mathematics for teaching into the analyses. The Mathematical Knowledge for Teaching–Algebra developed by ETS and the University of Michigan as part of the Measures of Effective Teaching Project (Melinda Gates Foundation and Educational Testing Services, 2012) was administered to faculty participants prior to the start of the Fall 2017 semester to measure their knowledge for teaching. The Faculty Beliefs about Mathematics and Mathematics Teaching survey developed at the University of Maryland (Campbell, 1990) was used to gather faculty beliefs. Midway through the semester student perceptions of the instructional practices of their instructor were collected via the TBI (Murray, 1987; Murray & Renaud, 1995), a 56-item instrument that describes the instructional practices experienced by students in the classroom.

Outcome Variable. Participating instructors provided the students’ final grades as a letter grade and as a percentage from 0 to 1. Scales used to assign letter grades vary by institution, so we chose to continue our analysis using students’ percentage grade as opposed to the letter grade for the outcome variable.

Models

Multiple linear regression was performed to study the effect of student-level and instructor-level variables on the outcome of percent grade. The data used in the model was gathered from 20 IA instructors with 272 students and 24 CA instructors with 365 students across the participating institutions. The main effects in the model, identical for IA and CA groups, were built using the demographic variables, APCR-

$$\widehat{\text{PercentGrade}} = \beta_0 + \beta_1(\text{Male}) + \beta_2(\text{Age}) + \beta_3(\text{Hispanic}) + \beta_4(\text{Asian}) + \beta_5(\text{Black}) + \beta_6(\text{Mixed}) + \beta_7(\text{Other}) + \beta_8(\text{FirstLanguage}) + \beta_9(\text{Caregiver}) + \beta_{10}(\text{Work}) + \beta_{11}(\text{GPA}) + \beta_{12}(\text{MinorAssistance}) + \beta_{13}(\text{MajorAssistance}) + \beta_{14}(\text{APCR Posttest}) + \beta_{15}(\text{DifficultProblems}) + \beta_{16}(\text{Understanding}) + \beta_{17}(\text{Effort}) + \beta_{18}(\text{Useful}) + \beta_{19}(\text{SelfEfficacy}) + \beta_{20}(\text{StudentPerformance}) + \beta_{21}(\text{TeacherMastery}) + \beta_{22}(\text{MaleTeacher}) + \beta_{23}(\text{FullTime}) + \beta_{24}(\text{MathPD}) + \beta_{25}(\text{NonMathPD}) + \beta_{26}(\text{InformalPD}) + \beta_{27}(\text{TASMD}) + \beta_{28}(\text{TMIM}) + \beta_{29}(\text{TASSP}) + \beta_{30}(\text{MKT})$$

	Intercepts, Gender and Age
	Race or Ethnic Group
	Other Demographics
	Score on APCR Posttest
	Student Beliefs
	PALS
	Teacher Demographics
	Professional Development
	Teacher Behavior Inventory

Equation 1: Regression model for IA and for CA groups

CC final score, student beliefs factors, PALS, and instructor level variables (see Equation 1). Student demographics included are gender, age, race or ethnic group, if English is their first language, if they are a primary caregiver, if they are employed at least 40 hours per week, and high school GPA (coded dichotomously: less than 2.5 as 0 and greater than or equal to 2.5 as 1).

Preliminary Findings

Variable	Model 1 (College Algebra)	Model 2 (Intermediate Algebra)
APCR Final Score	0.064 (0.031)*	0.089 (0.033)**
Male (student)	-0.112 (0.028)***	-0.043 (0.032)
Age	0.002 (0.036)	0.102 (0.039)*
Race		
Hispanic or Latino	-0.157 (0.032)***	-0.054 (0.033)
Asian American	0.032 (0.030)	0.035 (0.032)
Black or African American	-0.090 (0.034)**	-0.044 (0.033)
Mixed race	0.008 (0.026)	0.012 (0.031)
Other	0.027 (0.024)	0.051 (0.032)
English as first language	-0.031 (0.033)	0.030 (0.035)
Primary care giver	-0.043 (0.033)	-0.013 (0.034)
Full time job	-0.043 (0.033)	-0.074 (0.035)*
HS GPA < 2.5	0.000 (0.032)	-0.056 (0.035)
Public assistance		
Minor source	0.028 (0.027)	-0.055 (0.032)
Major source	0.022 (0.029)	-0.041 (0.030)
Student beliefs		
Difficult problems	-0.040 (0.036)	0.012 (0.040)
Understanding	-0.017 (0.031)	0.041 (0.036)
Effort	0.033 (0.033)	0.001 (0.036)
Useful	-0.016 (0.034)	-0.030 (0.040)
PALS		
Academic self-efficacy	0.197 (0.035)***	0.182 (0.041)***
Student performance	-0.010 (0.028)	-0.026 (0.030)
Teacher mastery	-0.049 (0.031)	-0.061 (0.038)
Male (instructor)	0.090 (0.041)*	-0.053 (0.035)
Full time instructor	-0.094 (0.042)*	0.011 (0.041)
Years of teaching experience	0.002 (0.033)	0.091 (0.040)*
Professional development		
Math specific	0.104 (0.043)*	0.069 (0.054)
Non-math specific	0.005 (0.044)	0.056 (0.069)
Informal	0.210 (0.048)***	-0.076 (0.048)
Teacher beliefs		
TASMD	-0.020 (0.033)	0.000 (0.051)
TMM	0.062 (0.046)	0.010 (0.048)
TASSP	0.001 (0.046)	0.018 (0.043)
MKT	0.041 (0.043)	-0.084 (0.046)
Intercept	0.402 (0.027)***	0.449 (0.030)***
R ²	0.33	0.29
Adjusted R ²	0.27	0.20
n	365	272

Note. ***p<0.001, **p<0.01, *p<0.05

Table 1: Standardized coefficients for linear regression

Standardized results for both IA and CA are presented in Table 1. In both groups, APCR-CC final scores and PALS Academic Self Efficacy were statistically significant at a $p < 0.05$ level. For every one standard deviation increase in APCR-CC final score, on average, the predicted percent grade increases by 0.064 standard deviations in the CA group and 0.089 standard deviations in the IA group, respectively. For every one standard deviation increase in PALS Academic Self-Efficacy, on average, the predicted percent grade increases by 0.197 standard deviations for the CA group and 0.182 standard deviations for the IA group, respectively. Moreover, Years of Teaching Experience was statistically significant for the IA group, where the predicted percent grade increases by 0.091 standard deviations, on average, for every one standard deviation increase in Years of Teaching Experience. For the CA group, both Math Specific Formal Professional Development and Informal Professional Development were statistically significant. For every one standard deviation increase in Math Specific Formal Professional Development, on average, the predicted percent grade increases by 0.104 standard deviations, and for every one standard deviation increase in Informal Professional Development, on average, the predicted percent grade increases by 0.21 standard deviations for the CA group. There were other variables in either of the two groups that were statistically significant (see Table 1).

The analysis with CA students and with IA students both had adjusted R^2 values that, while not overly large, are considered substantial for an observational study in education (Hill, et. al., 2008). The adjusted R^2 values for the two groups are in the range of 20% – 30%. That is, the model predictors explain 20% – 30% of the variance in the outcome variable, percent grade.

Discussion

The preliminary results from these analyses suggest that (a) the APCR-CC final score, (b) PALS Academic self-efficacy score, and (c) instructors' years of mathematics teaching experience and exposure to professional development opportunities are positively associated with the students'

outcome on course percent grade. The demographics of students taking these courses and the nature of the content taught in these two courses may explain the degree to which the APCR-CC can be used as a predictor and the extent to which these instructor factors affect the students' opportunities to learn.

Given that the APCR-CC was designed to measure readiness for CA and pre-calculus, it is not surprising that APCR-CC final scores are a good predictor of students' final grades in both courses. Students who were able to do well on the APCR-CC, which tested conceptual understanding, were more likely to do well in their course. What might be surprising are the respective effects of APCR-CC final score increases to the grade increase for both IA and CA group of students. IA students' grades seemed to respond more to APCR-CC score increases than their CA counterparts. This main effect was somewhat tempered in the CA courses, which command a deeper conceptual understanding of proportionality, linearity, covariational reasoning, exponential growth, rational function behavior, and an ability to leverage these ideas to create models for problem solving.

Since the PALS Academic Self-efficacy scale measures academic related perceptions, beliefs, and strategies of the student, it is not surprising that students who have a higher score in the academic self-efficacy scale perform better in their course. Research has shown that a students' self-efficacy appears to be a critical factor for student success and performance with an extensive body of research showing a positive association between academic self-efficacy and college grades (Barber, 2009). Thus, we confirm prior research regarding the role of motivation on performance, with the very specific population of community college students taking algebra courses (Mesa 2012).

The students' opportunities to deepen their understanding of concepts taught in these algebra courses were positively impacted by the instructors' years of teaching experience and exposure to professional development (PD). We posit that duration of teaching experience had a positive impact on the IA course because: (i) the course is calculational in nature, and (ii) students in these courses may be repeating the course (after previously seeing the content in high school). These two factors make years of teaching experience a valuable trait for an instructor teaching this course because the instructor becomes efficient in teaching ways of doing (as opposed to ways of thinking), and instructors can also anticipate students' common pitfalls and offer pre-remediation. On the other hand, exposure to PD had a positive impact on CA students' opportunities to learn. These students are typically encountering the largely conceptual content taught in this course for the first time. IA courses tend to be more about simplifying expressions and solving equations while CA tends to be more about reasoning about and modelling with functions. Thus, teaching IA involves developing students' fluency with algorithms while teaching CA involves developing students' facility with functions, a topic that is historically elusive to students and slow to develop. The complexity of teaching mathematics (Potari, 2012) in ways that develop students' conceptual understanding, especially on elusive challenging topics such as functions, puts extra demands on instructors to teach in innovative ways, that are largely different from the ways the instructors encountered mathematics instruction when they were students. Professional development opportunities, both formal and informal have the potential to positively affect instructors' efficacy (Zambo & Zambo, 2008) by exposing instructors to the nature of mathematics and to effective practices in mathematics education that lead to developing students' conceptual understanding. There is much we still need

to learn through our analyses of these instructors' teaching practices, which might shed further light into this issue. For example, we do not know the specific types of PD these instructors were exposed to, or how those PD opportunities impacted the instructors teaching practices. Based on these preliminary results, we recommend increasing PD opportunities for community college instructors, research into the specific types of PD these instructors are receiving, along with their corresponding impact on teaching and students' learning.

Moreover, all of the instruments (e.g., PALS) and the assessment (e.g., APCR-CC) used in the study were rigorously evaluated to establish the appropriate psychometric properties to ensure that the data collected during the course of the study were both valid and reliable. This psychometric validation process in itself is novel in the field of post-secondary mathematics education. We looked at the effects of each of these instruments and assessment on the outcome variable of percent grade in isolation, that is, after factoring out the variance from other variables in the model (e.g., demographic variables). We found significant effects of APCR-CC final scores, and the subscale - Academic self-efficacy from PALS survey on the outcome of percent grade, along with some other demographic variables. Analyzing each of these instruments and assessment in relation to the others can give us new perspectives on the relationships, which would otherwise be unavailable to us. Viewing research in this integrated way can help with the analysis of important outcomes of interest in a more comprehensive way. These findings have the potential to impact the way we measure student learning and consequently, the development of any professional development for the instructors, and/or student learning interventions. This work strived to provide a more holistic perspective on assessment and may provide direction for future creation of diagnostic assessments/instruments for assessing students in other contexts. Considerations for creating or modifying such diagnostic assessments/instruments for use by the research community should include the diversity of curricula, impact of culture, teaching techniques, and language as well as other factors that impact students' learning differently in different parts of the world.

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