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More than Math: On the Affective Domain in Developmental Mathematics

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Abstract

Students at a large urban community college enrolled in fourteen sections of a developmental algebra class. While cognitive variables are often used to place students, affective characteristics may also influence their success. To explore the impact of affective variables, students took ACT's Engage survey measuring motivation, academic-related skills and social engagement, as well as the ATMI (Attitudes Toward Math Inventory) survey. Student performance on the course was measured by a common 25 question multiple choice final exam. Of the affective variables measured, ATMI Motivation was statistically significant in positive correlation with final exam score, and ATMI Confidence had a statistically significant negative correlation. More general measures of motivation and confidence were not significant suggesting a potential difference affective measures for mathematics learning. Longer term persistence models indicated ATMI Value of Mathematics and Engage Academic Discipline were positive predictors of success.

Keywords

Affective characteristics, motivation, confidence, remedial mathematics, placement

Cover Page Footnote

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More than Math: On the Affective Domain in Developmental Mathematics

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Students at a large urban community college enrolled in fourteen sections of a developmental algebra class. While cognitive variables are often used to place students, affective characteristics may also influence their success. To explore the impact of affective variables, students took ACT's Engage survey measuring motivation, academic-related skills and social engagement, as well as the ATMI (Attitudes Toward Math Inventory) survey. Student performance on the course was measured by a common 25 question multiple choice final exam. Of the affective variables measured, ATMI Motivation was statistically significant in positive correlation with final exam score, and ATMI Confidence had a statistically significant negative correlation. More general measures of motivation and confidence were not significant suggesting a potential difference affective measures for mathematics learning. Longer term persistence models indicated ATMI Value of Mathematics and Engage Academic Discipline were positive predictors of success.

INTRODUCTION

Most college mathematics courses have prerequisites that are designed to ensure students have the background needed before attempting a course. For new students, colleges use a placement procedure to determine the students' most appropriate first course. Institutions must first decide what information will be used to determine this placement. Many students are required to take exams in order to graduate from high school, and the scores on these exams are often available from a student's high school record. In addition, many students who plan to go to college take the College Board's SAT exam or the ACT exam which are required by many institutions for admission. Community colleges are open-enrollment meaning there are few requirements for admission, and taking the SAT or ACT is typically not required. As a result, community colleges often have less student information available when making placement decisions.

To provide additional data to guide placement, colleges typically administer a placement test to new students. The placement decision is then often made solely on this single, high-stakes, cognitive assessment, typically either the ACT's Compass or the Educational Testing Service's ACCUPLACER (Gerlaugh, Thompson, Boylan, & Davis, 2007). However, as argued by Hughes and Scott-Clayton (2011), "the common assessments currently in use have some utility but are insufficient in terms of providing enough information to determine the appropriate course of action that will lead to academic progress and success for the vast range of underprepared students" (p. 20). These tests, they further argue, are most successful at predicting which students will do well in college level courses. Unfortunately, this is precisely opposite the target audience most influenced by them.

While cognitive measures influence student outcomes, there are additional non-cognitive, affective student characteristics which are related to student performance. Sedlacek (2004) includes among these attitudes toward learning, motivation, autonomy, desire to seek assistance, and willingness to put forth effort to learn. Bloom (1976) estimates that at least 25% of student performance is related to these affective factors. Nolting (1986) suggests that study skills, anxiety and locus of control also have a significant impact on math success. None of these affective characteristics are

measured by the cognitive tests typically used for placement.

Hunter Boylan, director of the National Center for Developmental Education, advocates the use of more comprehensive student profiles, including cognitive and noncognitive measures. Boylan (2009) suggests taking an inventory of "a range of affective characteristics such as motivation, attitude toward learning, help-seeking behavior, autonomy, anxiety, desire for peer or instructor affiliation, self-efficacy, and/or willingness to expend effort on academic tasks" (p. 17). Boylan further suggests using this broader student profile to guide at-risk students.

In Boylan's Targeted Intervention for Developmental Education Students (TIDES), institutions take an inventory of campus resources and then develop student profiles to advise students which resources are most beneficial in aiding their success. At the institutional level, this is a rather large undertaking involving coordination of data, advisement, and many campus offices. Despite the ambitious institution wide scope of the TIDES model, a more modest classroom based model may be of utility to instructors wishing to determine the best pedagogical practices to implement in classroom instruction.

Cognitive variables influencing student success are somewhat easily accessible to instructors who can often gather students' grades in prerequisite courses or give a diagnostic test of their own. Affective characteristics, however, require deliberate assessment not typically undertaken in the classroom. In this paper, we measure affective characteristics using two instruments. We use regression modeling to determine what impact these factors have on student learning. After learning how these characteristics influence achievement, we hope instructors can develop more holistic classroom interventions to improve student learning.

METHODS

At a large urban community college in the northeast United States, following the Institutional Review Board's approved protocol, fourteen developmental Elementary Algebra instructors consented to having a researcher attend a class meeting to administer surveys during the first two weeks of the spring 2012 semester. During this classroom visit, 233 of the 313 students present consented and completed our packet. This data was collected as part of a larger

study examining the efficacy of different pedagogical techniques. The results of that study are reported in another paper (Cornick, Guy, & Beckford, 2015).

General Affective Characteristics

We administered the Engage (formerly the Student Readiness Inventory, SRI) by ACT. Engage was developed to measure three student domains: motivation, academic-related skills, and social engagement. At the time of administration, it consisted of a 108 item, Likert-scale, pencil and paper survey. ACT generates two reports (student and advisor) with percentile scores on 10 qualities: Academic Discipline, Academic Self-Confidence, Commitment to College, Communication Skills, General Determination, Goal Striving, Social Activity, Social Connection, Steadiness, and Study Skills. The development and validation of Engage, including for use at community colleges, are detailed in multiple papers (Allen & Robbins, 2010; Gore, 2006; Le, Casillas, & Langley, 2005; Porchea, Allen, Robbins, & Phelps, 2010). In Table 1, we include a description of each domain and scale as found on the Engage website.

Mathematics Specific Affective Characteristics

While Engage provides us an opportunity to measure a wide range

of affective characteristics, it does not directly relate to mathematics. To address this, we supplemented Engage with the mathematics specific Attitudes Toward Mathematics Inventory (ATMI) (Tapia & Marsh, 2004). The ATMI is a 40 question Likert-scale survey. Four subscales are included: self-confidence in mathematics, value of mathematics, enjoyment of mathematics, and motivation for mathematics. We include a description of each scale and a sample item in Table 2. This instrument was used with permission of the creators. We administered this instrument on pencil and paper, but it could easily be administered electronically.

Cognitive and Demographic Variables

The affective measures were supplemented with cognitive variables gathered from the Office of Institutional Research and Assessment and classroom grade books provided by the instructors. We collected each student's score on the ACT/Compass placement exam in Pre-Algebra and Elementary Algebra. We also collected the student's College Admissions Average which is a GPA (out of 100) calculated only on college preparation courses taken during high school. We also factored in student's remediation needs in subjects other than mathematics.

In addition, we collected background demographic data in-

TABLE 1. Engage scale description.

Domain	Engage Scale	Definition	Sample Item
Motivation & Skills Personal characteristics that help students to succeed academically by focusing and maintaining energies on goal directed activities.	Academic Discipline	The amount of effort a student puts into schoolwork and the degree to which a student sees him/herself as hardworking and conscientious.	I turn in my assignments on time.
	General Determination	The extent to which one strives to follow through on commitments and obligations.	When I make plans, I follow through with them.
	Goal Striving	The strength of one's efforts to achieve objectives and end goals.	I strive to achieve the goals I set for myself.
	Commitment to College	Commitment to staying in college and getting a degree.	I'm motivated to get a college degree.
	Study Skills	The extent to which students believe they know how to assess an academic problem, organize a solution, and successfully complete academic assignments.	I highlight key points when I read assigned materials
Social Engagement Interpersonal factors that influence students' successful integration or adaptation into their environment.	Communication Skills	Attentiveness to others' feelings and flexibility in resolving conflicts with others.	In reaching an agreement, I consider the needs of others as well as my own needs.
	Social Connection	One's feelings of connection and involvement with the school community.	I have a sense of belonging when I am on campus.
Self-Regulation Cognitive and affective processes used to monitor, regulate, and control behavior related to learning.	Social Activity	One's comfort in meeting and interacting with other people.	I make friends easily.
	Academic Self-Confidence	The belief in one's ability to perform well in school.	I'm a fast learner.
	Steadiness	One's responses to and management of strong feelings.	I'm a patient person.

TABLE 2. Attitudes toward mathematics inventory (ATMI).

Scale	Description	Sample Item
Self-Confidence	The confidence category was designed to measure students' confidence and self-concept of their performance in mathematics.	I am able to solve mathematics problems without too much difficulty.
Value of Mathematics	The value of mathematics category was designed to measure students' beliefs on the usefulness, relevance and worth of mathematics in their life now and in the future.	Mathematics is important in everyday life.
Enjoyment of Mathematics	The enjoyment of mathematics category was designed to measure the degree to which students enjoy working mathematics and mathematics classes.	I have usually enjoyed studying mathematics in school.
Motivation	The motivation category was designed to measure interest in mathematics and desire to pursue studies in mathematics.	The challenge of math appeals to me.

cluding age, race, and gender. Our sample consisted of 233 developmental mathematics students. Our students were 61% majority female. The mean age was 21.4 (SD = 5.65, median = 19) years old. The ethnicity of our students were diverse with 34% Hispanic, 22% black, 15% white, 7% Asian, and the remaining indicating other or preferring not to respond.

Common Measure of Learning

Our goal was to determine how measurable affective characteristics impacted student learning. We used scores on the end of semester assessment required by all elementary algebra students. The elementary algebra final exam is a 25 question multiple-choice exam in which questions are equally weighted at four points each. The exam covers semester long learning objectives in elementary algebra. The score on this exam was used as our measure of mathematics achievement.

Data Analysis

Using SPSS, we created an ordinary least squares (OLS) regression model with the score on the final exam as the dependent variable. We included all the scales from Engage and the ATMI as continuous variables. We also included traditional predictors of student success including placement scores and high school GPAs. Of the affective variables included, only two affective variables ATMI Motivation ($p = .005$) and ATMI Confidence ($p = .032$) were statistically significant at the $\alpha = .05$ level. Age was statistically significant with

$p < .001$. The model had $R^2 = .274$.

The regression coefficient for ATMI motivation was 5.695, for ATMI confidence it was -4.578, and for age (in years) it was 0.971. All values represent points in score on the final exam per unit of measure.

As a follow-up to student success beyond this spring 2012 course, we tracked whether students enrolled in another math class at any time up to and including the spring 2014 semester. Using a logistic regression, we found an increase in the Engage Academic Discipline Scale Score was correlated with a 1.10 odds ratio ($p = .031$) of enrollment. As a note, we computed this same model only restricting the time frame for a student to enroll in another math course to only the semester following the study, and the results were not significantly different than the longer term measure. For consistency with the following model, we have omitted the shorter one here.

Following completion of remedial mathematics requirements, all students must enroll in and pass a credit-bearing mathematics course. We noted whether a student passed (with a C- or higher) a credit-bearing mathematics course any time up to and including the spring 2014 semester. Using a logistic regression, of the affective variables included, we found an increase in the ATMI Enjoyment of Mathematics score was correlated with a 2.14 odds ratio ($p = .027$), Engage Academic Discipline Scale Score with 1.10 odds ratio ($p = .011$).

DISCUSSION

Our final exam model showed that more motivation to study mathematics, which we measured at the beginning of the semester, was correlated with a higher score on the final exam. This finding is consistent with common practitioner belief and has been the topic of many research studies on motivation (e.g. Robbins et al., 2004; Weissberg & Owen, 2005). The Engage motivational scales were not significant, however. This may suggest that motivation to study mathematics may be a trait separate from other types of motivation. The differences between motivation for mathematics and more general motivation for studies warrants further investigation.

Somewhat more surprising was that more mathematical confidence at the beginning of the semester was correlated with a lower score on the final exam. While confidence is a common concern among instructors of students of low achievement, this model suggested that higher confidence at the beginning of the semester might have been more a cause for concern rather than lower confidence. While future studies are required to fully explain this and determine the persistence of this finding, one possible explanation is that developmental math students who start the term confident may tune out, since they are confident they can do the math. This could result in a lack of engagement with learning early in the semester. As a result, once the material progresses to a more difficult level, the student may not be engaged sufficiently to recognize their need. This may result in missing opportunities to reinforce supporting skills needed to complete the course successfully. A previous study by Schunk and Pajares (2004) also indicated that students with overly confident self-beliefs may not make good use of feedback.

A recent study highlighted gender differences among confidence in mathematics ability. In their study of college students, they found that men overestimated their mathematics abilities. In con-

trast to the findings by Schunk and Pajares (2004), after receiving feedback on their performance, men were able to accurately gauge their performance. Women in the study were more accurate at gauging their abilities without the initial feedback (Bench, Lench, Liew, Miner, & Flores, 2015).

After understanding confidence, we must develop interventions to support at-risk students. Targeting interventions toward mathematics students' confidence is a major cornerstone in the Carnegie Foundation for the Advancement of Teaching's efforts in developmental mathematics (Muhich & Yeager, 2012; Yeager, 2011). In their developmental mathematics courses, classroom instruction is explicitly geared toward improving student confidence and productive persistence. The study of confidence by Bench et al. (2015) suggests that there may be opportunities to improve student self-assessment and future performance by giving clear and targeted feedback.

Work by Bickerstaff, Barragan, and Rucks-Ahidiana (2012), which is based on student interviews, suggests that classroom experiences result in a shifting of confidence throughout students' careers. Their research presents multiple examples of how interactions with faculty and students influence and change student confidence. They state that, "students' experiences interacting with faculty and with others in their institution have an important impact on student expectations, motivation, and goals" (p. 4). Common practitioner focus on increasing confidence along with other studies (e.g. Cech, Rubineau, Silbey, & Seron, 2011) on increasing confidence suggest our negative correlations of initial student confidence may be especially interesting to study in a larger population using additional measures.

While not an affective variable, age is a non-cognitive variable of interest. In our study, older students performed better on the final exam. Previous studies on age as a predictor of success and persistence in community colleges have been mixed. In the research on persistence between semesters Fike and Fike (2008) found age to be a non-predictor (fall to fall retention) or a very weak predictor (fall to spring retention). In contrast, the study by Trueman and Hartley (1996) found older mature students report greater time-management skills which may allow more time to do well in college. Another study by Justice and Dornan (2001) found that older students use higher level cognitive study strategies which may also account for the improved performance. Differences in reasons for attending college also vary with age and may have an impact on student success (Wolfgang & Dowling, 1981).

In our model on final exam performance, many scales were not statistically significant. The two mathematical scales Value of Mathematics and Enjoyment of Mathematics did not correlate with success on the final exam. Interestingly, these two scales seem to relate to common practitioner concerns with teaching mathematics. It is commonly thought that if mathematics were more valued by students or if it were more enjoyable to students, then perhaps they will learn better. Our model suggests that having an inherent value of mathematics did not factor into final exam performance, and neither did a students' enjoyment of mathematics. However, when we expanded our scope to passing a credit-bearing course with a C- or higher, Enjoyment of Mathematics was a significant indicator of success. This perhaps suggests that this quality has a longer-term significance than the short-term performance on the final exam. Recent research by Clark, Middleton, Nguyen, and

Zwick (2014) suggested that enjoying learning is correlated with an increased GPA (another long-term measure). Future research targeting mathematical enjoyment compared to more general enjoyment for learning may also be informative.

In our longer-term logistic regression persistence models, the Engage Academic Discipline Scale Score showed significance as a positive predictor. The Academic Discipline Scale purports to measure conscientiousness, and our models support this claim.

Both the Engage and ATMI instruments were only administered to students at the beginning of the semester. We did this because our goal was to determine what types of characteristics instructors could assess and use at the beginning of the semester to guide their student supports. While several of the scales in these instruments were correlated with student success, we do not know if the students' scores on the scales changed throughout the term. As a result, we cannot say if student confidence, for example, remains negatively correlated to their performance if confidence changes throughout the course. Thus we do not know if an intervention should target these characteristics only at the beginning of the term or throughout. Moreover, we do not know if the affective characteristics we studied are malleable or causative. It is unclear if we can create interventions to increase the affective characteristics positively correlated to success, and it is moreover unclear if any increase in these characteristics would remain positively correlated to success. In future research, multiple measures of these characteristics throughout the semester may provide a clearer direction for improvement.

Since there were different instructors teaching students, it would also be of interest to repeat the experiment with a larger population with more instructors. In addition, all students in this survey were developmental math students. The affective characteristics that predict community college student success may vary with level of initial student placement, and this is worthy of study due to the breadth of difficulty of the courses offered at a community college.

CONCLUSIONS

If as instructors we hope to make significant progress toward better supporting student success and credential completion, we must reframe the all too frequent question of using background characteristics to predict which students will be successful with our current practices to a question of which practices best support students to be successful despite the student's negative outlook for success. In keeping with the spirit of TIDES, this will involve practitioners' attention to more than readily available cognitive variables and developing innovative ways to help their students to earn their success. Through continued experimentation with classroom practices and a wider view of student characteristics than traditionally considered, we may finally offer students their best opportunities to succeed.

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