ACT Research & Policy

Technical Brief

Development and Validation of a STEM Benchmark Based on the ACT STEM Score

Justine Radunzel, PhD

Krista Mattern, PhD

Jill Crouse, PhD

Paul Westrick, PhD

In fall 2015, ACT will introduce a STEM score for the ACT® test that will provide students and educators with more insight into critical aspects of college readiness.[1] Developed in response to the national focus on student deficiencies in math and science, the score is derived from ACT mathematics and science test scores and represents students' overall performance in these subjects. This brief presents validity evidence for using the ACT STEM score as an indicator of students' readiness for college coursework in science, technology, engineering, and mathematics (STEM) disciplines.

A recent ACT research report suggests that academic readiness for STEM coursework may require higher scores than those suggested by the ACT College Readiness Benchmarks given that Calculus instead of College Algebra appears to be the typical first mathematics course of students majoring in STEM.[2] The median ACT mathematics test score associated with a 50% probability of earning a B or higher grade in Calculus is 27. The typical first science course taken is largely dependent upon a student's major, as evidenced by differences between the four STEM major clusters included in ACT's definition of STEM.[3] Based on performance in Chemistry, Biology, Physics or Engineering, the median ACT Science score associated with a 50% probability of earning a B or higher grade is 25. In comparison, the ACT College Readiness Benchmarks in mathematics and science are 22 and 23, respectively.[4]

Two types of validity research are presented in this brief. The first involves identifying the ACT STEM score that is associated with a reasonable chance of success in first-year STEM-identified mathematics and science courses. This information can be used to help gauge overall student readiness for STEM-related coursework. The second type examines the ACT STEM score in relation to the likelihood of succeeding in a variety of STEM-related college outcomes: cumulative grade point average (GPA) over time, persistence in a STEM major, and ultimately completing a STEM degree. These results illustrate that predicting student success in STEM-related fields is a valid use of the ACT STEM score.

Justine Radunzel is a principal research scientist in Statistical and Applied Research specializing in postsecondary outcomes research and validity evidence for the ACT test.

Krista Mattern is a director in Statistical and Applied Research specializing in the validity and fairness of assessment scores as well as more general issues in higher education such as enrollment, persistence, and graduation.

Jill Crouse is a senior research associate in Educational and Workforce Research Services specializing in postsecondary research and report development.

Paul Westrick is a research scientist in Statistical and Applied Research specializing in postsecondary outcomes research and validity evidence for the ACT test.

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ACT Technical Briefs provide reliability, validity, and other psychometric analyses on ACT education and workforce development assessments, services, and programs and those of its partners. For more on the ACT test, visit www.act.org.

Course Success

When combining grade data for Calculus and multiple science courses from an earlier study into a single course-success model, the typical ACT STEM score associated with at least a 50% chance of earning a B or higher grade in a STEM-related course is 26. The ACT STEM score of 26 also corresponds to the average of the ACT mathematics (27) and science (25) scores, which were derived by using separate STEM content area course-success models for Calculus and a combination of science courses.[5] Given that a STEM score will be reported on the ACT score report, it is appropriate that the STEM readiness benchmark be developed based on that score rather than the mathematics and science scores separately. That being said, the two STEM readiness definitions (i.e., ACT STEM score ≥ 26 versus ACT mathematics score ≥ 27 and ACT science score ≥ 25) reach similar conclusions with regard to which students are classified as STEM-ready. For the 2014 ACT-tested high school graduating class, 93% would be classified consistently under the two definitions of STEM readiness: 13% would be STEM-ready and 80% would not be STEM-ready under either definition.[6] Of the 7% that would be classified differently under the two definitions, all of the cases were STEM-ready based on the ACT STEM score ≥ 26 definition but were considered not STEM-ready based on the ACT mathematics score ≥ 27 and ACT science score ≥ 25 definition. The disparities are due primarily to students not earning an ACT mathematics score of 27 or higher.

Figure 1 shows that as students' ACT STEM scores increase, the typical chances of earning a B or higher grade in STEM-related courses also increase. The median probability of earning a B or higher grade across the two content areas as a function of ACT STEM score is greater than 50% for students with an ACT STEM score of 26 or higher and is at least 75% for those with an ACT STEM score of 31 or higher.[7] The probability of earning a C or higher grade is also plotted in Figure 1. For students with an ACT STEM score of 26 or higher, students' chances of earning a C or higher grade are greater than 75%.

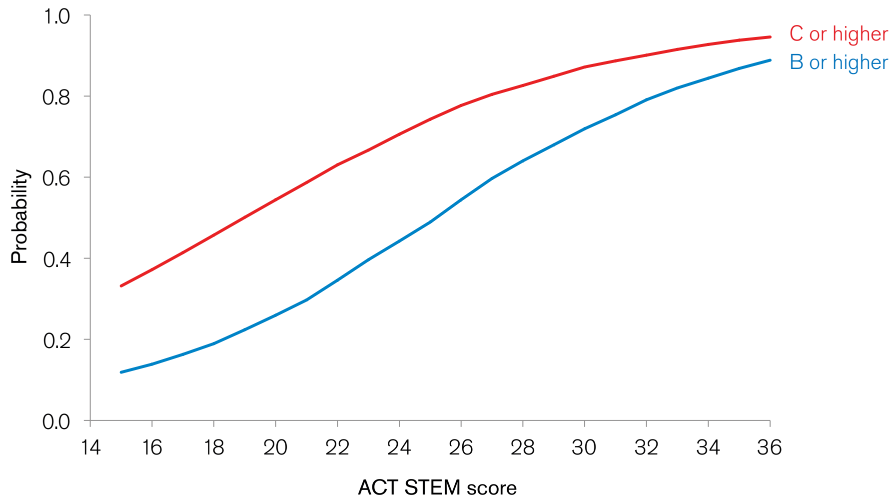

Figure 1. Probability of success in STEM-related courses by ACT STEM score at a typical four-year institution. The math-related course is Calculus. The science-related courses include Chemistry, Biology, Physics, and Engineering.

In contrast to the rates for students who appear to be ready for STEM coursework, students with lower ACT STEM scores, such as a 22 or below, have at most a 35% chance of earning a B or higher grade in a STEM-related mathematics or science course. Their chances of earning a C or higher grade in STEM-related courses are below 65%. (For reference, students who meet neither of the ACT College Readiness Benchmarks in mathematics and science will have an ACT STEM score of 22 or below.)

Results from supplemental analyses suggest that the typical highest percentage of correct classifications (that is, the maximum accuracy rate) across institutions for using the ACT STEM score to predict course success in Calculus and STEM-related science courses is consistently greater than 60%.[8] For Calculus, the typical rate was 64%, with an interquartile range (IQR) of 61% to 69% across institutions. For the individual science courses, the typical accuracy rate was 66% for Physics (IQR = 63% to 74%), 67% for Chemistry (IQR = 64% to 72%), and 69% for Biology (IQR = 65% to 73%). The median increase in the percentage of correct classifications associated with using the ACT STEM score over classifying all students as STEM-ready was 11% to 12% in Calculus and Physics and 21% to 22% in Chemistry and Biology.

Cumulative GPA

ACT STEM scores are not only related to course success in individual mathematics and science courses. They are also related to achieving a specific cumulative college GPA over time among students in STEM majors. Figure 2 illustrates the positive relationship between ACT STEM score and first-year college GPA. It indicates that higher ACT STEM scores are associated with a higher likelihood of achieving a specific first-year college GPA at a typical four-year postsecondary institution.[9] For example, students' chances of earning a first-year GPA of 3.0 or higher are 20 percentage points higher for students majoring in STEM with an ACT STEM score of 26 than for those with an ACT STEM score of 22 (63% and 43%, respectively). Figure 2 also illustrates the positive relationships between ACT STEM score and GPAs of 2.0 or higher and 2.5 or higher.

Additionally, STEM persisters—students who persisted in a STEM major—with higher ACT STEM scores are more likely than those with lower scores to achieve a cumulative college GPA of 3.0 or higher beyond year 1. Focusing on STEM persisters ensures that a majority of students' grades are earned in STEM-related courses. As shown in figure 3, the chances of achieving a 3.0 or higher cumulative GPA are 70% at year 2, 72% at year 3, and 74% at year 4 for STEM persisters with an ACT STEM score of 26. The corresponding chances are 17 to 20 percentage points lower for STEM persisters with an ACT STEM score of 22 (50%, 54%, and 57%, respectively).[10]

STEM Persistence

In terms of STEM persistence, students with higher ACT STEM scores are more likely than those with lower scores to persist in a STEM major over time. This finding is observed not only at year 2, but also at years 3 and 4 (figure 4).[11] Additionally, STEM attrition is

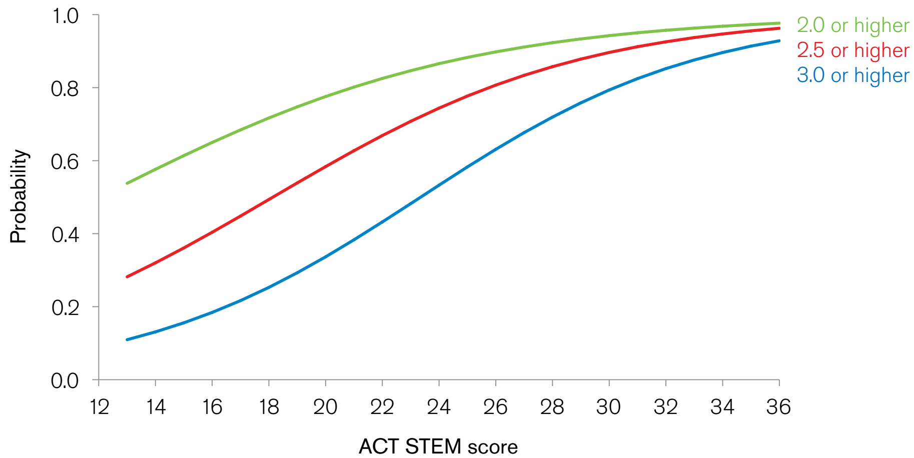

Figure 2. Probability of achieving specific first-year college GPAs by ACT STEM score for STEM majors at a typical four-year institution

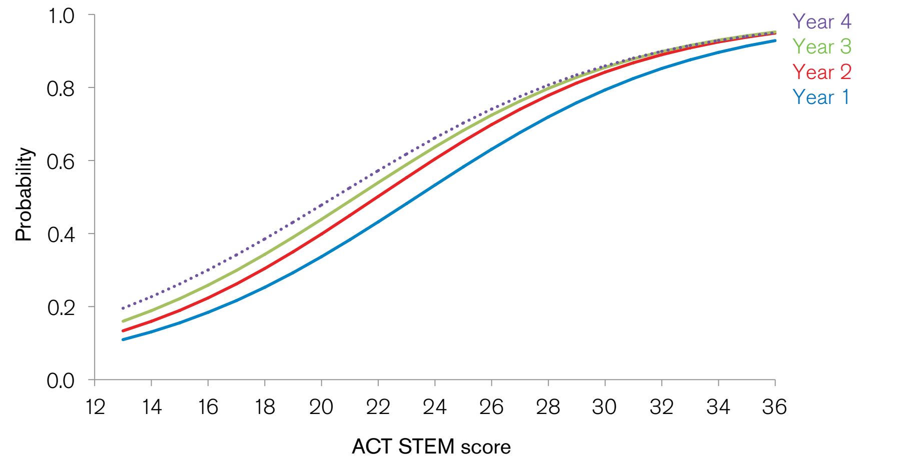

Figure 3. Probability of achieving a cumulative college GPA of 3.0 or higher over time by ACT STEM score among STEM persisters at a typical four-year institution

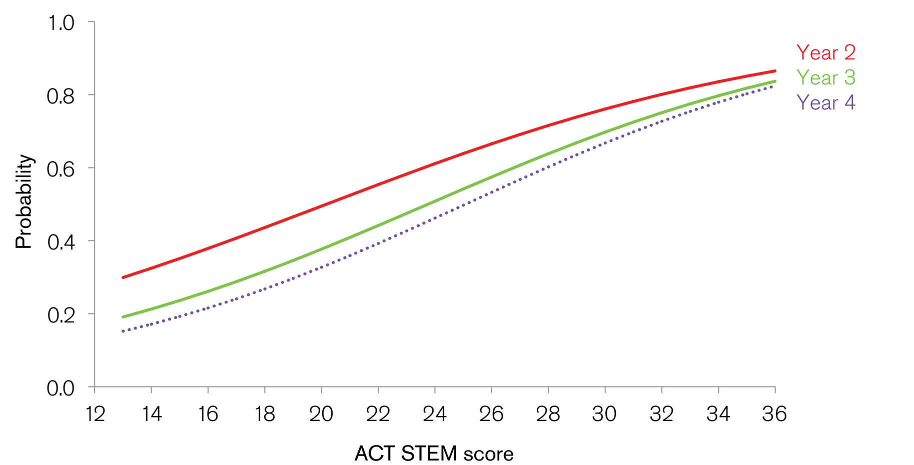

Figure 4. Probability of persisting in a STEM major at years 2, 3, and 4 by ACT STEM score at a typical four-year institution

less likely to occur over time among students with higher ACT STEM scores.

The chances of persisting in a STEM major are 67% at year 2, 57% at year 3, and 53% at year 4 for students with an ACT STEM score of 26. In comparison, students' chances are 12 to 14 percentage points lower across the years for those with an ACT STEM score of 22 (55%, 44%, and 39%, respectively).

STEM persistence status at year 4 was accurately predicted by the ACT STEM score for 63% of the students majoring in STEM in the study sample.[12] Moreover, among students predicted to persist to year 4 based on their ACT STEM score, 67% actually persisted in a STEM major at year 4. Conversely, of those predicted not to persist, 61% did not persist in STEM at year 4. Similar percentages were observed for the STEM persistence outcomes at years 2 and 3.

STEM Degree Completion

Not only are students majoring in STEM with higher ACT STEM scores more likely to persist in a STEM major through year 4, but they are also more likely to complete a degree in a STEM field. This finding is illustrated in figure 5 for STEM majors at a typical four-year institution with substantial differences observed between those with higher and lower ACT STEM scores.[13]

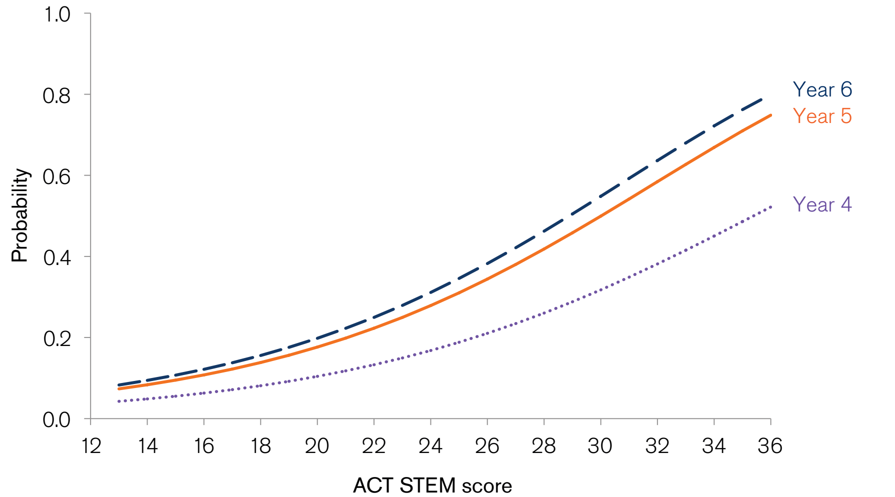

Figure 5. Probability of completing a bachelor's degree in a STEM field at years 4, 5, or 6 by ACT STEM score at a typical four-year institution

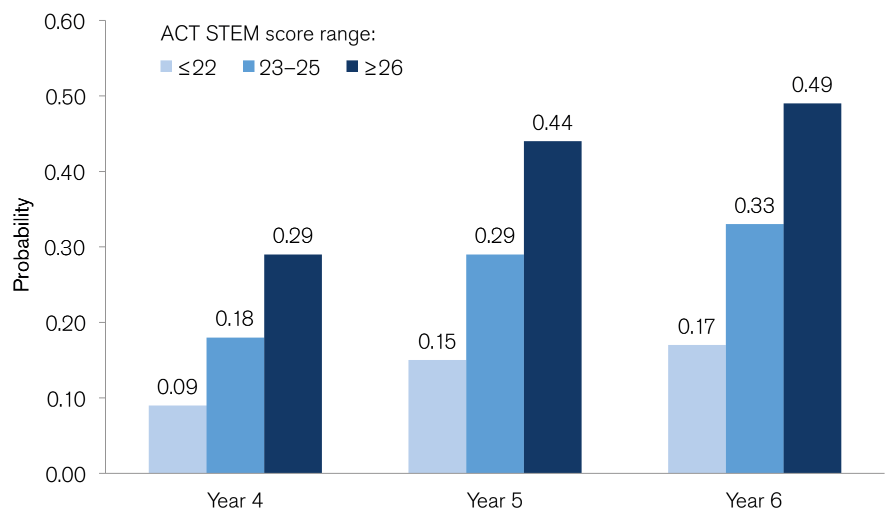

Figure 6. Probability of completing a bachelor's degree in a STEM field at years 4, 5, or 6 by ACT STEM score range at a typical four-year institution

For students majoring in STEM with an ACT STEM score of 26, the chances of completing a bachelor's degree in a STEM field within four, five, or six years of initially enrolling in college are 21%, 34%, and 38%, respectively. Students with STEM scores above 26 have even greater chances of success. For example, students' chances of completing a bachelor's degree in STEM within six years is more than 60% for students with an ACT STEM score of 32 or higher. In comparison, STEM majors with an ACT STEM score of 22 or below have only a 25% or smaller chance of doing so.

Figure 6 provides an alternative view of these results by examining STEM bachelor's degree completion rates by grouping students into three ACT STEM score categories: 22 or below, 23 to 25, and 26 or above. Students with an ACT STEM score of 26 or higher are nearly three times more likely than those with a score of 22 or below to earn a STEM degree within four, five, or six years (49% vs. 17% at year 6). Only one-third of students majoring in STEM with an ACT STEM score between 23 and 25 complete a STEM degree by the end of year 6.

Results for Students Who Began at a Two-Year Institution

In addition to the four-year sample results, the relationships between ACT STEM scores and STEM success for students attending two-year institutions were examined.[14] The outcomes are similar as those for the four-year sample, except in degree completion. For the two-year sample, completion of an associate's or bachelor's degree (for those who transferred) in STEM within 4, 5, or 6 years was evaluated.

Similar to the findings for the four-year sample, ACT STEM scores are positively related to students' chances of achieving specific cumulative GPAs over time, persisting in a STEM major over time, and completing an associate's or bachelor's degree in a timely manner for STEM majors who began at a two-year postsecondary institution. This result is illustrated in figure 7 for achieving a specific cumulative GPA and in figure 8 for completing an associate's or bachelor's degree in a STEM field.

Results by STEM Major Cluster

For each of the four STEM major clusters, students with higher ACT STEM scores are more likely than those with lower scores to succeed in STEM.[15] In particular, ACT STEM scores are positively related to students' chances of achieving specific cumulative GPAs over time, persisting in a STEM major over time, and completing a degree in STEM for each STEM major category. This finding holds for both the two- and four-year samples. Figure 9 illustrates this result for STEM persistence at year 4 for the four-year sample.

Conclusion

This report provides validity evidence for using the ACT STEM score to predict various outcomes of academic success. Irrespective of the outcome, students with higher ACT

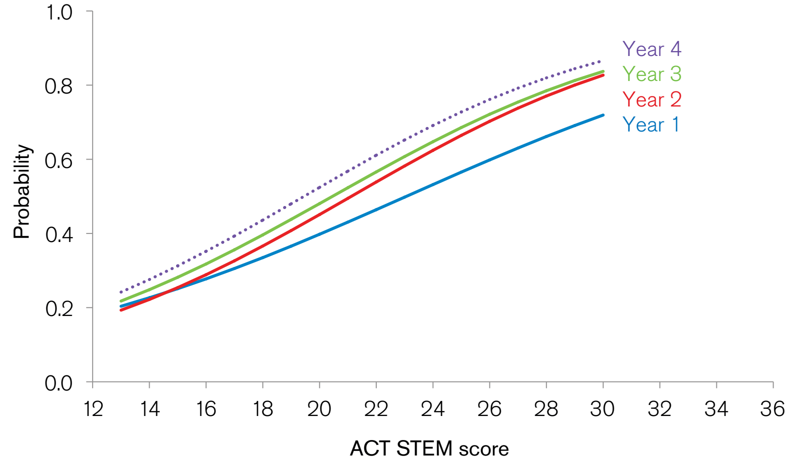

Figure 7. Probability of achieving a cumulative college GPA of 3.0 or higher over time by ACT STEM score among STEM persisters who began at a two-year institution

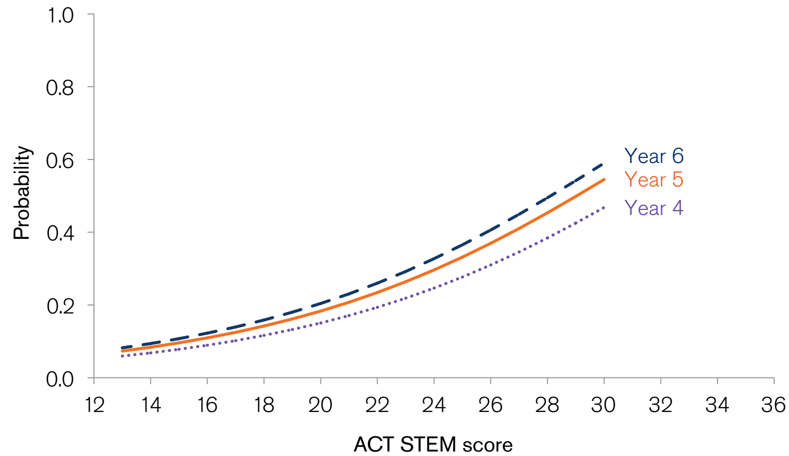

Figure 8. Probability of completing an associate's or bachelor's degree in a STEM field at year 4, 5, or 6 by ACT STEM score for STEM majors who began at a two-year institution

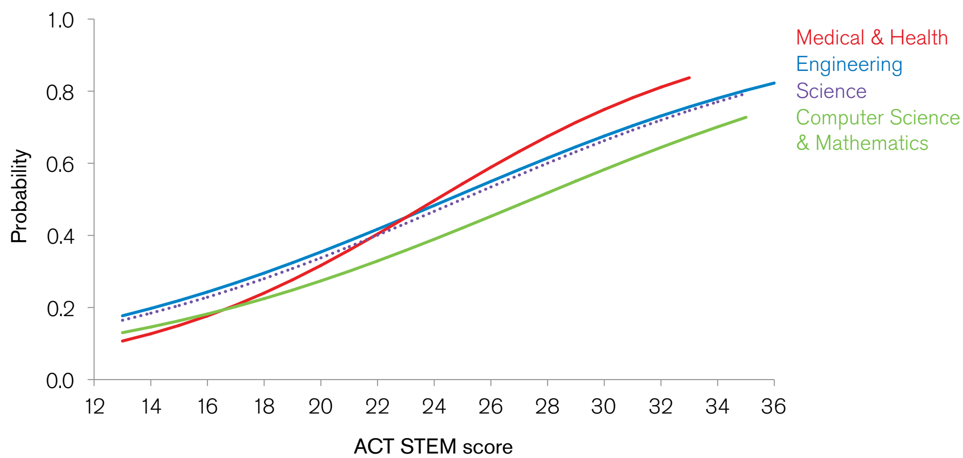

Figure 9. Probability of persisting in a STEM major at year 4 by ACT STEM score and STEM major cluster at a typical four-year institution

STEM scores are more likely to achieve success. Because measures of both science and mathematics are critical for gauging academic preparedness in STEM disciplines, ACT is uniquely positioned to provide feedback to students.

An ACT STEM score of 26 or higher is associated with at least a 50% chance of earning a B or higher grade in STEM-related courses such as Calculus, Chemistry, Biology, Physics, or Engineering. Students' chances of success continue to improve as ACT STEM score increases. In addition to the ACT STEM score, the individual ACT mathematics and science scores can be used to gauge student readiness for content-specific coursework, especially for STEM majors requiring Calculus-based mathematics and science courses such as engineering and mathematics.[16]

Clearly, there are other factors related to STEM success. For instance, the results in this report indicate a number of high-scoring students majoring in STEM do not complete a STEM degree, and some low-scoring students do. This finding is consistent with a growing body of literature that has found educational success is a product of not only academic skills and knowledge but of noncognitive factors as well.[17] Studies have shown that motivation, academic goals, and academic self-efficacy are significantly related to college grades and retention, even after controlling for socioeconomic status, high school GPA, and ACT/SAT scores.[18] In addition to the ACT STEM score, other measures that might be considered to help identify students who are likely to be successful in STEM-related fields include students' vocational interests, their high school coursework and grades, academic behaviors, and motivational factors.[19] ■

Notes

1 The STEM score is the rounded average of the ACT mathematics and science test scores. In addition to a STEM score, students will receive an English Language Arts (ELA) score, a Progress Toward Career Readiness indicator, and an Understanding Complex Texts indicator.

2 The ACT College Readiness Benchmark in mathematics was based on course grades earned in College Algebra. Krista Mattern, Justine Radunzel, and Paul Westrick, *Development of STEM Readiness Benchmarks to Assist Career and Educational Decision Making*, ACT Research Report 2015-3 (Iowa City, IA: ACT, 2015), http://www.act.org/research/researchers/reports/pdf/ACT_RR2015-3.pdf.

3 Given the inconsistency among various STEM definitions, ACT conducted a comprehensive literature review and refined its definition of STEM. One distinction of ACT's definition is that it excludes social/behavioral sciences such as psychology and sociology. The four STEM major clusters included in the definition are Science, Engineering & Technology, Medical & Health, and Computer Science & Mathematics. To learn more about the majors and occupations included in ACT's definition of STEM, see ACT, *The Condition of STEM 2013* (Iowa City, IA: ACT, 2014), http://www.act.org/stemcondition/13/.

4 In mathematics and science, 22 and 23 are the typical scores associated with at least a 50% chance of earning a B or higher grade in College Algebra and Biology, respectively. Jeff Allen, *Updating the ACT College Readiness Benchmarks*, ACT Research Report 2013-6 (Iowa City, IA: ACT, 2013), http://www.act.org/research/researchers/reports/pdf/ACT_RR2013-6.pdf.

5 For a description of the data, see Mattern, Radunzel, and Westrick, *Development of STEM Readiness Benchmarks*, 13. In the current analyses, the single ACT STEM score/course success model includes an indicator for content area (math versus science). Results are based on the typical probabilities of success across the two content areas giving equal weight to the two areas. The typical 25th and 75th percentiles across the two content areas are 25 and 27, respectively. The same ACT STEM cut score is suggested when the median probabilities of success are obtained from the separate content-specific course success models.

6 For students classified as not being STEM-ready by both definitions, 73.4% had an ACT mathematics score below 27 and an ACT science score below 25, 1.4% had an ACT mathematics score of 27 or higher and an ACT science score below 25, and 5.1% had an ACT mathematics score below 27 and an ACT science score of 25 or higher.

7 An ACT STEM score of 26 is the first score above the 0.50 threshold based on the median probabilities of earning a B or higher grade across the two content areas. Specifically, an ACT STEM score of 25 is associated with a median probability of 0.49, while for a score of 26 the corresponding probability is 0.54.

8 This finding is observed for several other mathematics and science courses such as College Algebra, Trigonometry, Precalculus/Finite Math, Anatomy/Physiology, Zoology, and Astronomy. Course success is defined here as earning a B or higher grade. Course grade data for these supplemental analyses are based on data from partnering institutions that have used ACT's Course Placement services (96 institutions/approximately 60,000 students for Calculus; 198 institutions/approximately 140,000 students for Biology; 106 institutions/approximately 110,000 students for Chemistry; 14 institutions/approximately 4,000 students for Physics with Calculus). The sample sizes here are greater than those used to develop the ACT STEM benchmarks in mathematics and science due to earlier freshman cohorts (prior to 2005) being included in these analyses (see Mattern, Radunzel, and Westrick, *Development of STEM Readiness Benchmarks*). The study sample is weighted to ensure that the sample is representative of a larger population of ACT-tested first-year college enrollees in terms of race/ethnicity, gender, ACT Composite score,

and high school GPA. The methodology for deriving the maximum accuracy rate is based on statistical decision theory for validating educational selection decisions and is the same as that used by ACT for helping institutions make course placement decisions. See Richard Sawyer, "Decision Theory Models for Validating Course Placement Tests," *Journal of Educational Measurement* 33, no. 3 (1996): 271–290. doi: 10.1111/j.1745-3984.1996.tb00493.x.

9 For a description of the data, see Mattern, Radunzel, and Westrick, *Development of STEM Readiness Benchmarks*, 18. Success rates are based on fixed-effect parameter estimates from hierarchical logistic regression models.

10 Students' chances of achieving a cumulative GPA of 3.0 or higher are likely increasing over time due to STEM attrition (e.g., students earning lower grades are more likely to switch to a non-STEM major or drop out of higher education), an outcome to be discussed in the next section.

11 For a description of the data, see Mattern, Radunzel, and Westrick, *Development of STEM Readiness Benchmarks*, 18. Success rates are based on fixed-effect parameter estimates from hierarchical multinomial regression models. Students were tracked primarily at the initial institution attended.

12 The predicted STEM persistence status for each student was based on their estimated chances of success derived using the fixed effect parameter estimates from the ACT STEM score model. If a student's chances were 50% or higher, they were predicted to persist (classified as persisting) in a STEM major.

13 For a description of the data, see Mattern, Radunzel, and Westrick, *Development of STEM Readiness Benchmarks*, 18. Success rates are based on fixed-effect parameter estimates from hierarchical discrete-time regression models. Students were tracked primarily at the initial institution attended.

14 Data are based on more than 10,000 students in STEM majors who first enrolled in one of 36 two-year institutions from two state systems (freshman cohorts 2005 to 2009). Success rates are based on fixed-effect parameter estimates from hierarchical regression models. Students were tracked across in-state two- and four-year postsecondary institutions, so in-state transfer information was available.

15 For the four-year sample, 28% were Engineering & Technology majors, 20% were Medical & Health majors, 11% were Computer Science & Mathematics majors, and 41% were Science majors. For the two-year sample, 26% were Engineering & Technology majors, 45% were Medical & Health majors, 13% were Computer Science & Mathematics majors, and 16% were Science majors.

16 Mattern, Radunzel, and Westrick, *Development of STEM Readiness Benchmarks*.

17 Krista D. Mattern, Jeremy Burrus, Wayne J. Camara, Ryan O'Connor, James Gambrell, Mary Ann Hanson, Alex Casillas, and Becky Bobek, *Broadening the Definition of College and Career Readiness: A Holistic Approach*, ACT Research Report 2014-5 (Iowa City, IA: ACT, 2014), http://www.act.org/research/researchers/reports/pdf/ACT_RR2014-5.pdf.

18 Steven B. Robbins, Kristy Lauver, Huy Le, Daniel Davis, Ronelle Langley, and Aaron Carlstrom, "Do Psychosocial and Study Skill Factors Predict College Outcomes? A Meta-Analysis," Psychological Bulletin 130, no. 2 (2004): 261–288.

19 Justine Radunzel, Krista Mattern, and Paul Westrick, "More Than Test Scores: A Multidimensional Model of STEM Success" (Paper presented at the annual forum for the Association of Institutional Research, Denver, CO, May 28, 2015).