2018 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
STEAM - SCIENCE, TECHNOLOGY & ENGINEERING, ARTS, MATHEMATICS & EDUCATION
JUNE 6 - 8, 2018 PRINCE WAIKIKI, HONOLULU, HAWAII

STRATEGIES TO CORRELATE ADMISSION CRITERIA TO PERFORMANCE IN STEM COURSEWORK FOR NON-SCIENCE MAJORS

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Strategies to Correlate Admission Criteria to Performance in STEM Coursework for Non-Science Majors

Synopsis:

STEM classrooms challenge students to make conceptual applications across disciplines. The question is, can we predict STEM performance before they enter the classroom? We assessed standardized exam and individual predictors (i.e., demographics, athletics, etc.) along with the likelihood of graduation using the consolidated college entrance examination rank (CEER). Our data supports a conclusion that composite predictors are useful to identify students who may benefit from additional interventions to ensure successful progress towards graduation

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ABSTRACT

The ACT and the SAT are the most commonly used standardized college entrance examinations. The ACT assesses four areas: English, math, reading, and science; the SAT examines reading, writing and language, and mathematics. At the United States Military Academy, (USMA) we use an additional metric, called the college entrance examination rank, or CEER score. CEER is a composite predictor of academic success, as measured by likelihood of graduation, which considers class ranking, faculty evaluations, extracurricular activities, and school ranking, The CEER is used to classify students into three categories: at-risk, average, and scholar populations. Together, these criteria on the individual and aggregate level were compared to actual STEM performance across the core curriculum requirements in chemistry, math, physics, and biology. Additionally, since biology (for non-majors) is their final science course taken at the Academy, we administered the biology concept assessment tool (BCAT) to specifically measure gains in the area of chemistry, heredity, evolution, and human physiology and assessed how comparative gains following instruction related to CEER.

RESULTS: The CEER score was most predictive of performance in STEM coursework for the at-risk population and upper end of the scholar population. Less predictive value was found for the average population. Specifically CEER was best at predicting biology and chemistry, physics, and calculus course grades for the at-risk population (below the course averages) and the upper end of the scholar population for biology and chemistry. CEER was not predictive for the average population nor was the scholar group measurably different in physics, math, or calculus scores. Notably, BCAT post-test scores were improved to a similar extent for all three CEER categories, indicating that course instruction was effective across ability levels. The BCAT gains best correlate not only with CEER scores but also biology course grades in the areas of “chemistry and the cell,” “heredity and gene regulation” and “evolution and origins of life” sections but not at all with the “human physiology” portion of the course. Taken together, our data suggests that composite pre-admission assessments are potentially useful predictors for STEM performance. These predictors can identify students who may benefit from additional intervention and remediation opportunities to ensure successful academic progress towards graduation as well as provide quantitative evidence for deliberate curriculum adjustments.

Key Words: course assessment, predictors of success, admissions criteria, non-STEM major performance, standardized exams

INTRODUCTION

A liberal arts education, such as that offered at the United States Military Academy, West Point, requires foundations in both humanities and science. Students not majoring in STEM (science, technology, engineering, and math) fields find themselves in required courses for which they may have minimal preparation, and, frankly, interest. From a STEM perspective, this offers educators an interesting opportunity to engage humanities majors in the process of science rather than focus on the minutiae of facts to cultivate critical thinking skills (National Science Foundation, 2009) to solve ill-defined problems. Non-major students are often faced with challenges when asked to draw conceptual applications or apply previous coursework in chemistry, math, and physics.

In order to cultivate these core concepts and scientific literacy in a student centered classroom faculty must identify instruments to best assess student performance (AAAS, 2011). Instructors serve as the key "tour guides" for mapping concepts across disciplines. However, this begs the question, can we predict student performance in STEM through direct or indirect mechanisms before they step foot into the classroom?

Cadets at the United States Military Academy (USMA), West Point, are exposed to many core requirements during their undergraduate experience. Every cadet must complete a core STEM sequence which includes three science courses, one of each from chemistry, physics, and the third can be a continuation in chemistry, physics, or a (first and last) course in biology. We wondered whether we could accurately predict cadet academic performance prior to instruction. Our goal was to assess whether Academy-level pre-admission criteria, specifically the College Entrance Examination Rank (CEER), would correlate to STEM performance.

The admissions process at the US Military Academy considers the whole candidate perspective with the CEER score predicting the likelihood of graduation. CEER is described at length elsewhere (Hanser, 2015) but, in general, encompasses standardized exams, high school ranking, grade point average, faculty evaluations, athletic abilities, and community involvement in a 360 degree approach to assessing potential candidates for admission. While top tier academic performers certainly are present, some cadets arrive with academic challenges. CEER allows the categorization of students into "at-risk", those potentially at-risk for graduation who may require additional interventions, and "scholars" or students who should excel without additional assistance. The remaining "average" category are cadets who may or may not benefit from remediation or should not pose a risk for successful graduation.

With the introduction of non-majors biology to the curriculum, we wanted to assess the effectiveness of instruction and degrees of student gains. Previous studies have used concept inventories to assess gains in learning (Sundberg, 2002; Crowe, Dirks, & Wenderoth, 2008). Concept assessment tools exist for several disciplines such as physics (Hallound & Hestenes, 1985), chemistry (Landis, Ellis, & Lisenky, 2001) and microbiology (Marbach-Ad & et.al., 2010). However, a single instrument was not available for a one-semester non-majors biology course. Our Department of Life Science faculty selected 30 multiple choice questions, the Biology Concept Assessment Tool (BCAT) that spanned the biology course objectives covering the areas of chemistry, heredity, evolution, and human physiology. The one-semester introduction to biology course was first offered during the fall 2016, with its development influenced by *Vision and Change in Undergraduate Biology Education* (AAAS, 2011). For most, this would be their final science course taken at the Academy. It was of particular interest to emphasize the inter-disciplinary nature of applied sciences by bridging previous coursework and this was reflected on the BCAT.

Our hypotheses are i) The College Entrance Examination Rank (CEER) can predict success in five STEM courses; ii) An internally developed Biology Concept Assessment Tool (BCAT) will successfully track learning in four areas of the capstone non-majors biology course; and iii) The classroom experience in Biology will lead to improvements for students of all abilities on the Biology Concept Assessment Tool.

METHODS

Use of human subjects

This study was reviewed and granted exempt status by the United States Military Academy (USMA) Human Research Protection Program (CLS 17-001).

Student population

All cadets were enrolled in the one-semester introduction to biology course for non-majors. Students had previously completed one semester of general chemistry along with coursework in mathematical modeling, with concurrent completion of calculus and one semester of physics, as part of the core curriculum. This biology course was first offered in the fall 2016 and as of fall 2017 six hundred ninety-three cadets have completed the course. These are primarily humanities majors in their second year of studies at the Academy, scheduled to graduate in 2019.

Of the 1,115 cadets in the class of 2019, twenty-two percent are female and 23.5% are recruited athletes (USMA, 2017). Their average academic program score (GPA in academic courses) was 3.015 and average College Entrance Examination Report (CEER) score was 618. CEER Scores factor ACT, SAT, high school rank, physical fitness score, athleticism, extracurricular activities, and faculty evaluations (Hanser, 2015). The stratification of CEER scores, corresponding to graduation probability, delineates <520 to be academically at-risk and >649 as scholars.

Comparison of CEER and STEM coursework

During the second year that introduction to biology was offered we compared student performance in previous coursework (final course averages) of chemistry, physics, math modeling, and calculus. Data from the fall 2017 term reflect those who had completed biology (269; 0.84); general chemistry I (252; 0.80); math modeling (242; 0.84); calculus (228; 0.80);

and physics (177; 0.78) (number of students and course average in parenthesis).

Concept Inventory

The Biology Concept Assessment Tool (BCAT), 30 multiple choice questions, was administered to address a wide coverage of STEM concepts in chemistry, heredity with applied mathematics, evolution, and human physiology. The BCAT committee selected questions from test banks provided by course selected text publisher, Pearson's MasteringBiology and Campbell's Essential Biology with Physiology, 5th edition (Campbell, Simon, Dickey, & Reece, 2016). The test was digitally administered via BlackBoard (Blackboard, 2016). This required Respondus Lockdown browser (Respondus, 2017), a program which disables all computer functions and internet access beyond the exam. All introduction to biology cadets completed the BCAT as part of Lesson 1 homework and during the final exam. Scores were compiled at the individual and aggregate levels. The average time to completion was 23 minutes (+/- 5 minutes).

Comparison of CEER and course events

BCAT performance was compared to CEER score categories of at-risk (<520), average (521- 648) and scholar (>649). This was further analyzed by the overall BCAT percentage and by course block content of chemistry, heredity, evolution, and physiology. Normalized gains for BCAT [(Post-course score – Pre-course score)/(100% - Pre-course score)] (Hake, 1998) where negative values indicate a decrease in performance while positive values denote the percentage gain normalized to initial performance were compared using Friedman's test and Dunn's posttest at 95% CI, *** $p<0.001$, ** $p<0.01$ (n=401). Additionally, performance within these categories was compared to the respective content on the final exam (term end exam or "TEE") at the aggregate level. On an individual basis, CEER categories and course performance was compared to normalized gain. Data was analyzed by Spearman correlation analysis.

RESULTS

CEER and STEM course performance. The West Point cohort is unique in several aspects. As mentioned, although the cadets are non-science majors they are still required to complete courses in calculus, chemistry, and physics. Compliance is not an issue as cadets are required to complete all formal course events and also required to attend classes. We compared CEER scores to individual STEM performance in biology, chemistry, physics, math modeling, and calculus courses (Figure 1). In general terms, as CEER scores increase so do course averages. The correlation was strongest for biology and chemistry courses. Particularly for the at-risk students, CEER was predictive for performance at or below the STEM course averages. Cadets with average CEER scores perform somewhat equally above and below the course averages. Notably, when cadets are classified as scholar category, the CEER becomes less predictive of performance as several cadets scored below the course average and, in a select few cases, approached course failure.

Pre- and post-test BCAT gains across CEER categories. In a measure of effectiveness of instruction for all learners, the BCAT averaged an overall 5.46 question improvement post-instruction compared to the beginning of the course. Overall, there was a difference in pre- and post-course BCAT scores when considering CEER category (Figure 2A). Similarly, these differences were mirrored for post-course BCAT averages across course content in chemistry, heredity, evolution, and physiology (Figure 2 B-E). After normalization, the average BCAT gains were highest in human physiology (0.47 +/- 0.25) and heredity (0.45 +/- 0.23) followed by evolution (0.23 +/- 0.15) and chemistry (0.13 +/- 0.10). While all CEER categories exhibit improved normalized BCAT gains (Figure 2F), the lowest overall gains were observed in the at-risk categories, which did not exceed 0.45. Likewise, low CEER score students performed at or below the biology course average, without exception. There was not clear distinction between high CEER scores and normalized BCAT gains (Figure 2F), although this population generally achieved 0.15 or higher gains while the average CEER scores reflect a combination of positive and negative gains. This suggests that at-risk CEER is predictive of performance at or below the course average with limited normalized BCAT gains while the upper end of CEER scholars achieve positive gains with the majority of the population above the course average.

Correlation between BCAT and biology course performance. Results on the BCAT post-test paralleled course grades (TEE - Term-end exam) on three of the four course sections: chemistry and the cell, heredity and gene regulation, and evolution and origins of life, but not for the human physiology portion of the course (Figure 2 B-E).

The normalized gains on the BCAT were lowest for the *chemistry and the cell* portion of the course. The initial BCAT assessment was surprisingly low as well as the post-course performance, contributing to the low normalized gains (Figure 3). This is surprising considering that all students had completed one semester of general chemistry. Given their similar performance on the chemistry portion of the final exam (Figure 2B), we suggest that although students can comprehend chemical concepts, they struggle with applied analysis in the context of biology. As a STEM capstone course for non-majors, the questions on both the BCAT and the biology term end exam were conceptual, high order taxonomy, which presented challenges as cadets were often able to perform recall of data type tasks, as demonstrated in previous coursework, but synthesizing or creating new information presented challenges not as frequently encountered. With this course being their first exposures to heredity, evolution, and human physiology, we suggest that learning higher order applications for the first time led to improved gains in these areas compared to chemistry (Figure 3).

DISCUSSION

West Point aspires to educate a diverse set of young leaders who demonstrate intellectual competence and the ability to think critically (USMA, Educating Army Leaders, 2017). One way to cultivate this intellectual capacity is by requiring courses in STEM to promote agile thinkers who are able to deal with the shifting missions of the Army (Jebb, 2017). With cadets arriving with a wide range of intellectual skills and backgrounds, our goal was to provide a quantitative evaluation of STEM performance for cadets enrolled in core biology for non-science majors. Our hypothesis was that the USMA predictor of academic success, the CEER score, would correlate with STEM-related course performance. Specifically, we hypothesized that entrance scores and admissions analysis using the composite CEER scores would be able to discriminate high-performing students from those at risk for success in STEM courses. We determined that CEER, rather than individual ACT or SAT scores, is useful as an academically at-risk predictor across STEM coursework with performance trending at or below course averages. However, this model is less predictive for the average and scholar population. Together, CEER is useful to identify cadets, pre-admission, who may benefit from early academic enhancement or intervention strategies.

For the first iteration of a non-majors biology course, we designed the course with a deliberate assessment plan which included a biology concept assessment tool (BCAT). It was administered on the first day of the course and then again at the end of the course. Gains were measured against pre-course predictors of success. Results of our study indicate that the highest normalized gains are at the average to scholar levels and that the at risk populations struggle not only with the BCAT but with course averages. This is not surprising. However, it was surprising that there is not a clear delineation between the average and scholar categories. This illustrates one limitation of applying admissions based criteria, standardized tests or high school performance to the collegiate environment. It was also surprising that the cadets did not perform as well on chemistry-related questions, a course which all students had completed as one semester pre-requisite. Previous concept inventory strategies (Newcomer & Steif, 2008) explored follow-up interviews with students via written explanations as to why they selected their answers. For future purposes, this could provide insightful for STEM programs offered within our department. Using aggregate averages, normalized gains, and individual performance on the BCAT, cadets averaged a five (of 30) question improvement following the course. It was also important to determine that our methods of instruction resulted in similar gains in all three CEER categories.

Taken together, we suggest that composite pre-admission predictors of successful graduation are useful to consider. This approach can identify sub-populations who can benefit from early interventions or faculty referrals to available academic services for specific or targeted assistance to promote continuous improvement and successful entry into a career of service.

ACKNOWLEDGEMENTS

We appreciate the dedication of the Academy to evaluate prospective candidates during the admissions process and the Office of the Dean for assistance with data collection. We acknowledge the support of the Department of Chemistry and Life Science Core Biology Team who provided the framework and expertise to enact this novel endeavor and the Corps of Cadets within the classrooms that made this study possible. The views expressed are those of the authors and do not reflect the official views of the US Military Academy, the US Army, or the Department of Defense.

Figure 1. Relationship of CEER score to Individual STEM performance.

Individual CEER score is compared to performance in one-semester courses of **A)** biology, **B)** chemistry, **C)** physics, **D)** mathematical modeling, and **E)** calculus. The solid box denote “at-risk” students, based on CEER scores, while the dotted boxes indicate “scholars”. Green lines represents the course average. Results indicate performance of the same cadets who had completed these courses as of fall 2017. Specific numbers are found in Appendix 1. [r values (correlation coefficient): (biology 0.4215); (chemistry 0.431); (physics 0.2292); math modeling 0.2751); (calculus 0.2943).

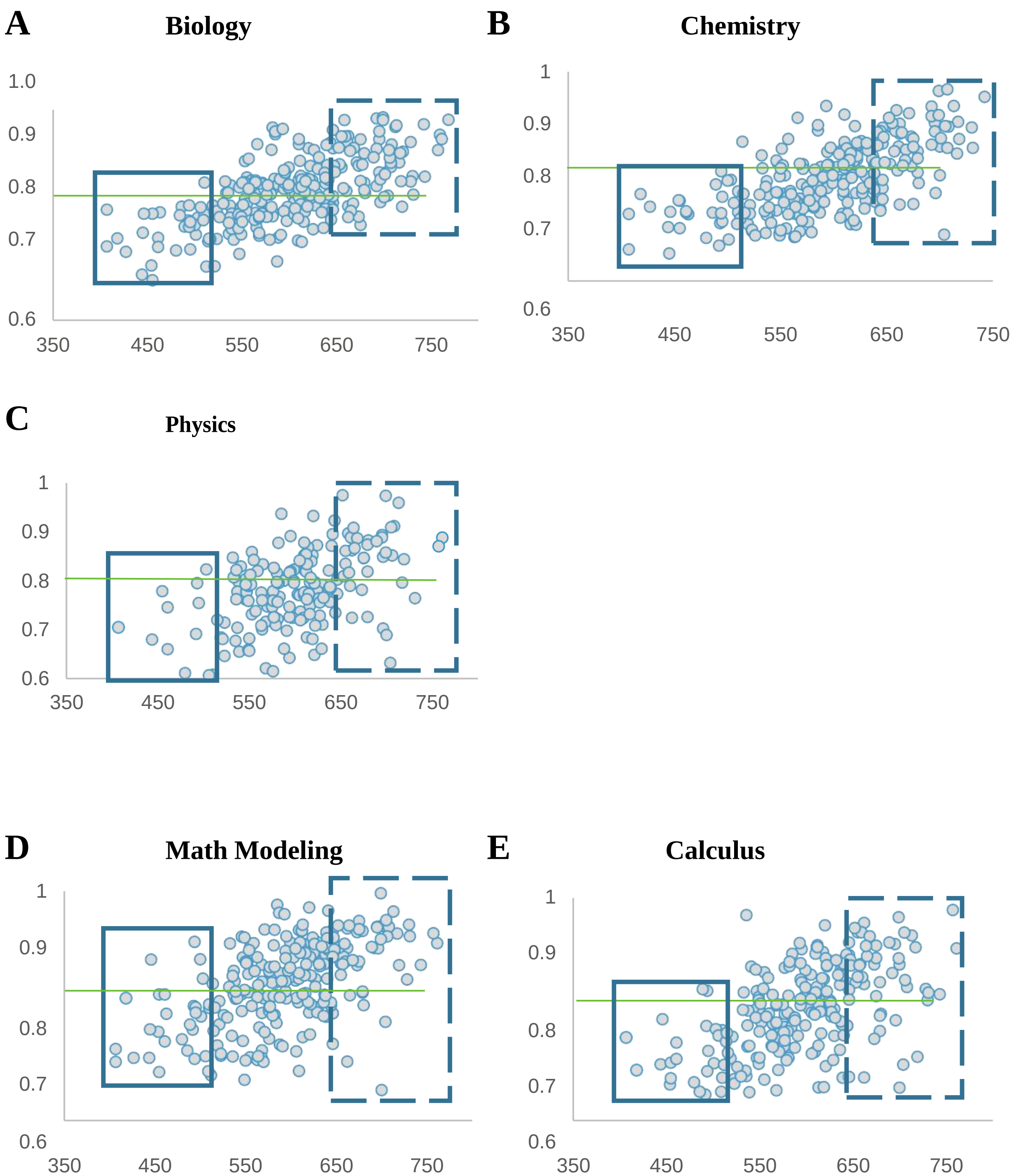


Figure 2. BCAT performance compared to CEER score and final exam performance.
A) Cadets were separated by CEER score with comparison of average BCAT performance between cadets enrolled at the beginning (Pre-) and end (Post-) of introductory biology (non-major, n=134). Bars are mean ± 95% CI; data were analyzed by Mann-Whitney test; ***, $p < 0.001$. **B-E)** By CEER score categories, the average post-BCAT performance within each subject matter of the biology course (chemistry, heredity, evolution, & human physiology) was compared to average for the relevant course content on the term end exam (TEE). Data represents fall 2016 cohort (n=130). Bars are mean + 95% CI. **F)** The normalized BCAT gain is stratified by CEER category and final biology course average. Data were analyzed by Paired t test. ***, $p<0.001$; **, $p<0.01$.

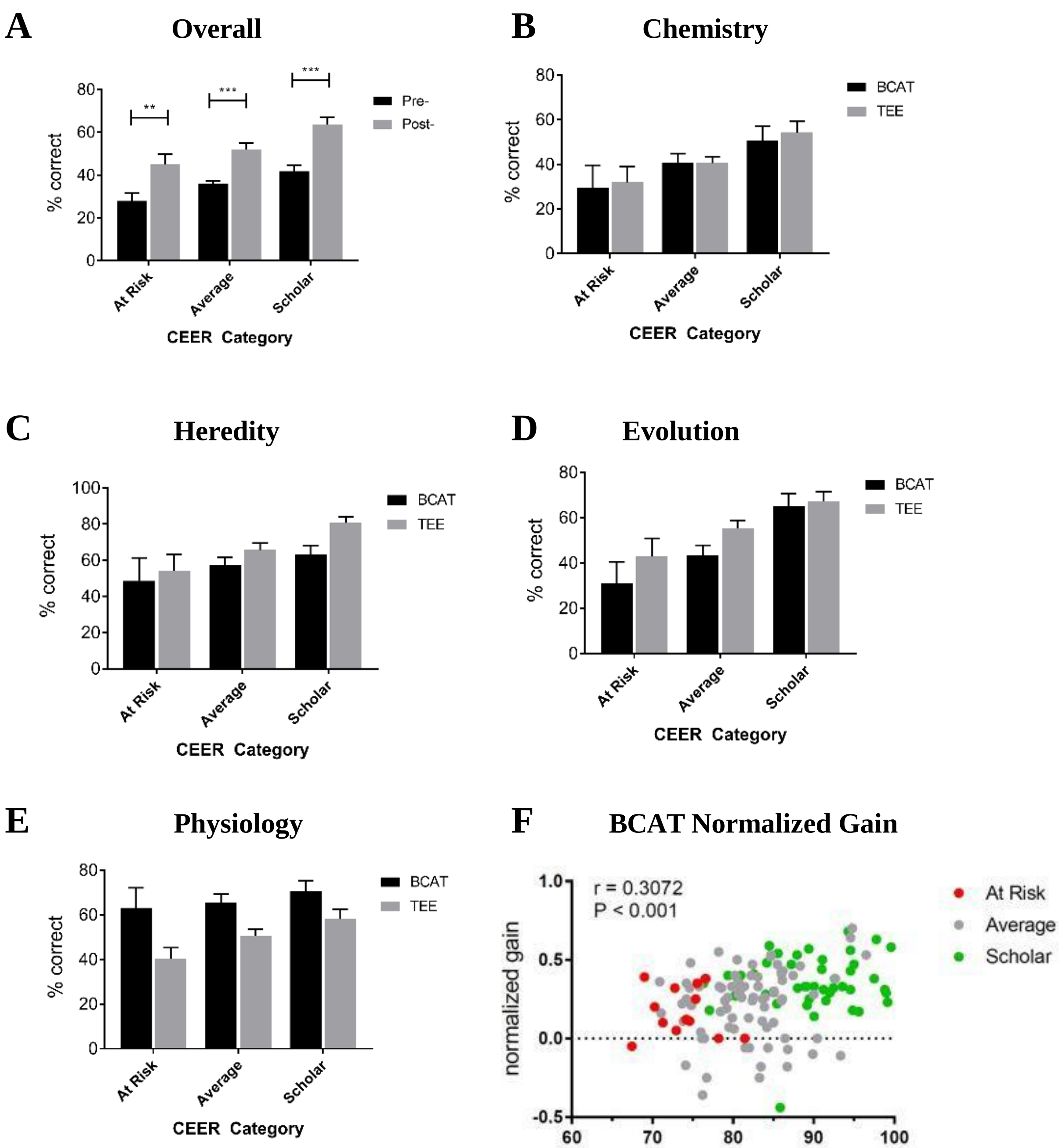
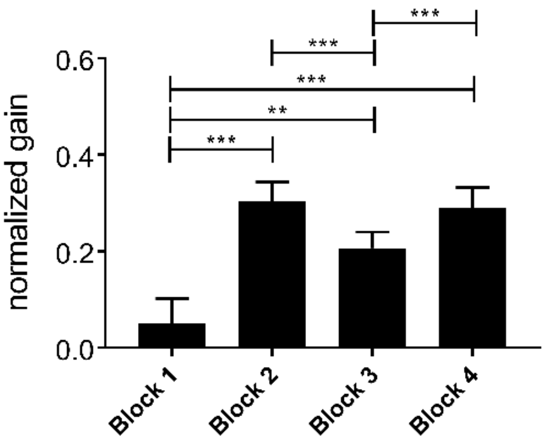


Figure 3. Comparative gains attributable to biology instruction.
BCAT gains were normalized for individual performance on the pre- versus post-course assessments [(post-course – pre-course) / (100% - pre-course)]. The normalized gain for BCAT sections assessing each block of the introductory biology course are shown, with results reflecting the aggregate of academic year 2017 (n=401), and compared using Friedman's test and Dunn's posttest. Bars are mean + 95% CI. ***, $p<0.001$; **, $p<0.01$.



Block 1—Chemistry & the Cell
Block 2—Heredity & Gene Regulation
Block 3—Evolution
Block 4—Human Physiology

REFERENCES

AAAS. (2011). American Association for the Advancement of Science. *Vision and Change in Undergraduate Biology Education: A Call to Action*: A Summary of Recommendations Made at a National Conference Organized by the American Association for the Advancement of Science. Washington DC. Retrieved from http://visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf

Blackboard. (2016). *Blackboard Learn 9.1 Release Q2 2016 CU3.* United States Military Academy. Retrieved from http://www.blackboard.com/

Campbell, N., Simon, E., Dickey, J. H., & Reece, J. (2016). *Essential Biology with Physiology.* Pearson.

Crowe, A., Dirks, C., & Wenderoth, M. P. (2008). Biology in Bloom: Implementing Bloom's Taxonomy to Enhance Student Learning in Biology. *CBE-Life Science Education, 7*, 368-381.

Hake, R. (1998). Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. *American Jouranl of Physics*, 64-74. doi:http://dx.doi/org/10.1119/1.18809

Hallound, I., & Hestenes, D. (1985). The Initial Knowledge State of College Physics Students. *Americal Journal of Physics, 53*, 1043-1055.

Hanser, L. &. (2015). *United States Service Academy Admissions Selecting for Success at the Military Academy/West Point and as an Officer.* Santa Monica: RAND Corporation.

Jebb, C. (2017). *Preface: Educating Army Leaders.* West Point, NY: US Military Academy. Retrieved from https://www.usma.edu/strategic/SiteAssets/SitePages/Home/Educating%20Army%20Leaders_Jan%202018.pdf

Landis, C., Ellis, A., & Lisenky, G. (2001). *Chemistry ConcepTests: A Pathway To Interactive Classrooms.* Pretice-Hall.

Marbach-Ad, G., & et.al. (2010). A Model for Using a Concept Inventory as a Tool for Students' Assessment and Faculty Professional Development. *CBE-Life Sciences Education, 9*, 408-416.

National Science Foundation (2009). Preface to Vision and Change in Undergraduate Biology Education: A Call to Action. *Vision and Change in Undergraduate Biology Education: A Call to Action* (pp. viii-ix). Washington, DC: American Association for the Advancement of Science.

Newcomer, J., & Steif, P. (2008). Student Thinking about Static Equilibrium: Insights from Written Explanations to a Concept Question. *Journal of Engineering Education, 97*(4), 481-491. doi:10.1002/j.2168-9830.2008.tb00994.x

Respondus. (2017). *Respondus 4.0 LockDown Browser.* Retrieved from http://www.respondus.com/products/lockdown-browser/

Sundberg, M. (2002). Assessing Student Learning. *Cell Biology Education, 1*, 11-15.

USMA. (2017). *USMA Internal Public Reports.* West Point, NY. Retrieved from https://apps.usma.edu/ams

USMA. (2017). *Educating Army Leaders: Developing Intellect and Character to Navigate a Diverse and Dynamic World.* West Point, New York: United States Military Academy. Retrieved from https://www.usma.edu/strategic/SiteAssets/SitePages/Home/Educating%20Army%20Leaders_Jan%202018.pdf