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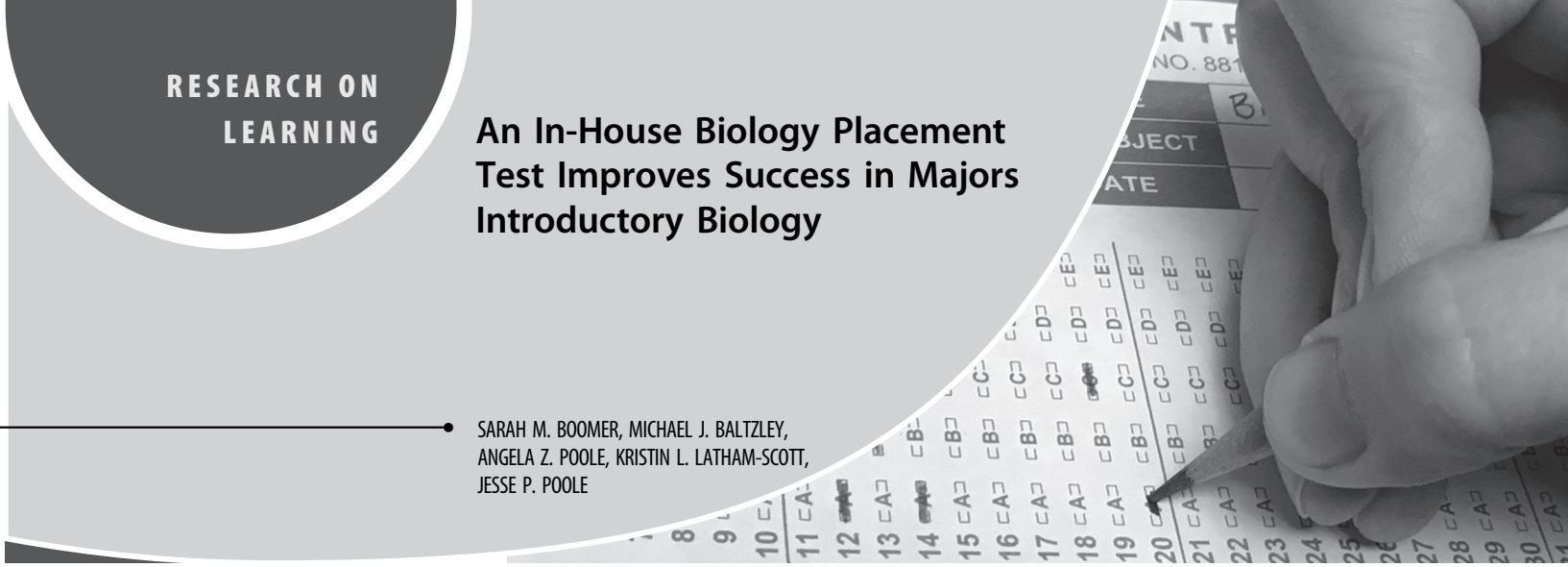
# An In-House Biology Placement Test Improves Success in Majors Introductory Biology



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**ABSTRACT**

*Biology placement tests (BPTs) have most often been used to determine whether well-prepared students can "test out" of foundational coursework at the college or university level. However, not all high school students are equally prepared for majors-level introductory Biology. Consequently, we developed and tested an in-house diagnostic BPT that assesses preparedness for "testing in" to introductory majors-level coursework (BI 211). We found that BPT scores were significantly correlated with final course grades. Following implementation of this benchmark, we documented short-term enrollment patterns of BPT-taking students (n = 313 over 3 years). Approximately half of these students passed the BPT, with 63 percent continuing in Biology. The other half did not pass, with 25 percent continuing in Biology. The implementation of the BPT decreased the overall percentage of F/Drop students in this course. These benchmarks have not affected the first generation college (FGC) or underrepresented minority (URM) enrollment in BI 211, nor have they introduced demographic biases among F/Drop students in this course. Given these data, we argue that diagnostic BPTs have an effective place in advising and retention strategies.*

**Key Words:** *biology placement test; biology education research; retention.*

## ○ Biology Placement Test Introduction: Testing Out, Testing In

Historically, biology placement testing has involved examinations that allow well-prepared students to test out of introductory courses or series. For example, the College Board's Advanced Placement Biology exam (http://apcentral.collegeboard.com) (Kastrinos & Erk, 1974) provides a fee-based option for pre-college students to test out of introductory coursework at many institutions. In contrast, we developed our BPT for the purpose of assessing student preparedness to test in to majors-level introductory biology (described in this paper). After independently making this decision in 2012, we performed an online search using the terms "biology placement test/exam" or "biology challenge test/exam." Our efforts yielded 34 U.S. programs that offer in-house BPTs (Table 1; additional information can be found at www.wou.edu/~boomers/boomer.html).

*Historically, biology placement testing has involved examinations that allow well-prepared students to test out of introductory courses or series.*

The majority of institutions who advertise BPTs (27/34) do so with a test out goal, allowing successful students to bypass prerequisite coursework covering biological molecules, cells, and genetics. Most of these programs (19 community colleges and 3 four-year institutions) use BPTs that allow qualified allied health students to move directly into 200-level health Anatomy & Physiology and/or Microbiology. Although most of these programs (13/22) do not describe their exam in detail, the others use exams ranging from 30 to 100 multiple choice and/or true/false questions focused on basic biology and/or chemistry. All of these programs require students to take tests in person, most at campus testing centers. Four institutions charge a fee ($10–$40), with one notably using HESI (Health Education Systems Incorporated, https://hesiinet.elsevier.com/, now Elsevier), a commercial instrument designed for assessing nursing program applicants. An additional five institutions, all four-year colleges or universities, have developed in-house BPTs aimed at allowing qualified biology majors to test out of majors-level introductory coursework or series, with most given in person during student orientation week in the fall.

Unfortunately, not all high school students have access to AP Biology, and even if they took a year of biology, K-12 biology standards are variable (Stansfield, 2011). Indeed, it has been demonstrated that many pre-college experiences (e.g., grades, content understanding, course structure, teaching style, math, SAT scores, parental education level, etc.) correlate with success in college biology (Loehr et al., 2012; Tai et al., 2006). Given increasing concerns about differential preparation, commercial placement tests for

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**Table 1. Institutions using biology placement tests.**

| | | |
|---|---|---|
| **Skip introductory course pre-requisites for allied health preparation** | | |
| Community Colleges | | |
| Arapahoe CC | DeAnza CC | Montgomery County CC |
| Arizona Western CC | Delgado CC | Oakland CC |
| Baltimore City CC | Front Range CC | Orangeburg-Calhoun Tech |
| CC of Denver | Glendale CC | Pikes Peak CC |
| Central Carolina CC | Lehigh Carbon CC | Wallace CC |
| Central New Mexico CC | Massasoit CC | Wallace State CC |
| Cuyahoga CC | | |
| 4-year Colleges and Universities | | |
| Alvernia U | CUNY Staten Island | John Jay C |
| **Skip introductory course for Biology Major** | | |
| 4-year Colleges and Universities | | |
| Brown U | U of Indiana Bloomington | Yale U |
| St. Cloud U | UNC Chapel Hill | |
| **Assess preparedness for introductory course for Biology Major** | | |
| Community Colleges | | |
| C of Southern Maryland | | |
| 4-year Colleges and Universities | | |
| Madonna U | Mills C | Wayne State U |
| Manhattanville C | U of Louisville | Western Oregon U |

assessing writing, reading, math, and chemistry (https://accuplacer.collegeboard.org/, https://www.aleks.com/) have been developed in the last decade to aid with the early advising process. To date, none of these companies offer biology placement testing, although the HESI exam includes biology. Some programs use chemistry placement tests developed in association with the American Chemical Society (Hovey & Krohn, 1963; Pienta, 2003), but biology lacks such an organization-driven tool (Pugh, 1988). For these reasons, seven institutions (including ours) have developed in-house diagnostic BPTs that assess preparedness for testing in to introductory majors-level coursework. In terms of the nature of these exams, we noted the most variety among this group, with some programs charging for a scheduled test, others offering free exams at scheduled/in-person times, and still others allowing students to take the test online and unsupervised.

Even though there are clearly many BPTs in use, we only identified one 1976 publication about test validation (White et al., 1976). In this report, we have described the evidence-based steps we have taken to develop, test, and analyze long-term data following BPT implementation and benchmark installation for our majors introductory course. Specific questions we addressed include: (1) How well does our BPT predict success in majors introductory biology? (2) How has BPT implementation and benchmark installation affected overall enrollment and success in majors introductory biology? (3) How has BPT implementation and benchmark installation affected cohort dynamics with respect to specific subgroups, including underrepresented minority (URM) and first generation college (FGC) students?

## ○ Course Context

Western Oregon University (WOU) is a public liberal arts, primarily undergraduate institution that serves approximately 5000 undergraduate students. Like many comparable universities, WOU serves a high proportion of FGC students (44% average between 2010 and 2015). An average of 2 students per year since 1997 have entered WOU with sufficiently high AP Biology scores to test out of introductory biology. To earn a biology degree at WOU, students begin by taking Biology 211 (BI 211), a majors-level introductory course focused on biological molecules, cells, and genetics. This course also serves chemistry and health–physical education majors. The Biology Department also offers a conceptual, non-majors series that fulfills general education requirements. This series includes Biology 102 (BI 102), which covers biological molecules, cells, and genetics, and serves many allied health students. During the time of this study (2013–2015), the average annual enrollment in BI 211 was 118 (offered Fall and Winter terms), and the average annual enrollment in BI 102 was 622 (offered year-round). An average of 27 WOU students per year graduated with biology degrees since 2010.

Prior to 2013, BI 211 had no pre-requisite benchmarks for entry, and the F/Drop rate was high, averaging 25 percent. Understanding these challenges, the BI 211 instruction team began formally studying this course in 2009, gathering background data, performing pre/post-test assessments using a suite of common exam questions to ensure consistency across sections, and surveying attitudinal information at the end of the course. Starting in 2009, we also implemented active learning strategies, including think-pair-share, clicker questions, modeling, partially flipped lectures, and problem-solving activities (Boomer et al., 2012, 2013; Boomer & Latham, 2011). Although active learning incorporation benefitted A/B/C students, our F/Drop rates were not changed. The students who failed or dropped the course often had serious attendance problems, failed to complete pre-course study exercises, and/or had low pre-test scores (Boomer et al., 2012, 2013; Boomer & Latham, 2011). These observations suggested that students lacked fundamental preparation to take this demanding majors-level course. Consequently, we decided to develop an in-house BPT to assess preparedness for testing into majors-level BI 211.

# ○ Methods

## BPT Development Research Design

Given our preparation-focused BPT aim, we adapted our BI 211 pre-test assessment instrument using the Oregon K-12 Science Standards from 2011. Content questions were specifically aligned to middle or high school standards. Six of the 30 sample BPT questions are shown in Table 2. We performed a trial run of our BPT with the 2012 BI 211 cohort ($n$ = 129 students). All students enrolled in

**Table 2. Sample BPT questions aligned to Oregon Science Standards.**

| Oregon Science Standard | BPT Sample Questions |
|---|---|
| Middle School: Describe the atomic model and explain how the types and arrangements of atoms determine the physical and chemical properties of elements and compounds. | *Which is found in the nucleus of an atom?*<br>a. protons only<br>b. electrons only<br>c. protons and electrons<br>d. protons and neutrons |
| High School: Compare and contrast the four types of organic macromolecules. | *Which is the most hydrophobic?*<br>a. proteins<br>b. lipids<br>c. carbohydrates<br>d. nucleic acids |
| Middle School: Explain the processes by which plants and animals obtain energy and materials for growth and metabolism. | *Photosynthesis produces*<br>a. carbon dioxide<br>b. water<br>c. oxygen<br>d. light |
| High School: Explain how cellular processes are regulated in response to the environment. | *A red blood cell in a high salt solution will*<br>a. explode<br>b. appear shriveled<br>c. appear normal<br>d. appear swollen but not explode |
| High School: Explain and apply laws of heredity and their relationship to DNA. | *Crossing two heterozygous individuals yields*<br>a. all dominant offspring<br>b. all recessive offspring<br>c. 1:1 dominant : recessive offspring<br>d. 3:1 dominant : recessive offspring |
| High School: Describe the structure of DNA and its relationship to chromosomes. Explain the role of DNA in protein synthesis. | *Reading RNA information into protein*<br>a. is called replication<br>b. is called translation<br>c. is called transcription<br>d. is called mutation |

BI 211 took this test the first day of class; they were given 30 minutes and informed that the outcome would not affect their course grade. We performed a regression analysis to determine if the final course grade was correlated with the BPT score. We only included students who completed all 4 course exams (3 midterms and a final exam). We also performed a contingency analysis to determine if the final grade distribution for students who passed the BPT (> 50%) was different than the grade distribution for students who did not pass the BPT. Students consistently earned the lowest scores on questions about cell division, genetic crosses involving probability/math, and gene expression; they earned the highest scores on questions about biological molecule structure and function, and genetic crosses involving blood-typing logic (data not shown).

### BPT Tracking Research Design

Following the formal adoption of our BPT, we tracked enrollment outcomes and cohort dynamics in all BPT-takers between 2013 and 2015 ($n$ = 317 students). Tracking involved mining transcript information to determine biology course enrollment choices students made within one year of taking the BPT.

### BI 211 Enrollment Research Design

For this part of the project, we defined two BI 211 cohorts: (1) The pre-benchmark cohort represented all students who enrolled in BI 211 between 2010 and 2012, prior to the installation of access benchmarks. (2) The post-benchmark cohort represented all students who enrolled in BI 211 between 2013 and 2015, after the installation of access benchmarks (i.e., earning 51% or higher on the BPT, or earning an A or B in BI 102, described in the results). We next compared annual enrollment numbers, the proportion of FGC students, and the proportion of URM students in BI 211 vs. incoming freshmen at WOU. URM students included individuals who identified as Native American, Native Alaskan, Hispanic, Black, African American, or Pacific Islander. Lastly, we used BI 211 background survey information to determine the proportion of FGC or URM students among specific BI 211 groups who failed (F/Drop) BI 211. Statistical comparisons between pre- and post-BPT implementation were performed using Chi-square analyses where we used the pre-BPT data to generate expected values for the post-BPT data.

### Human Subjects Research

All data were collected and analyzed within approved guidelines by the university institutional review board (IRB), ensuring ethical treatment of all participants. All BI 211 course instruments we designed are encompassed within an IRB-approved research project since 2009. Because many BPT takers never enroll in BI 211 (and were therefore not covered by the IRB-approved project), we requested and received supplementary IRB approval in 2015 to perform an archival study on this population. The latter also covers university data representing campus-wide enrollment and demographic data.

## ○ Results

### BPT Outcomes

We piloted the BPT on the 2012 BI 211 cohort ($n$ = 129 students). We found that BPT scores were significantly correlated with final course grades (Figure 1A; regression analysis: $p < 0.00001$). Additionally, students who passed the BPT with a score greater than 50 percent were much more likely to earn an A or a B in BI 211, and much less likely to fail or drop the course (Figure 1B; $X^2_{0.05,5} = 20.7$, $p < 0.001$).

Although we accepted scores of 51 percent on the BPT as passing, we encouraged students who scored between 51 and 70 percent to carefully consider their abilities and experiences in high school general biology, chemistry, and math as they chose whether to enroll

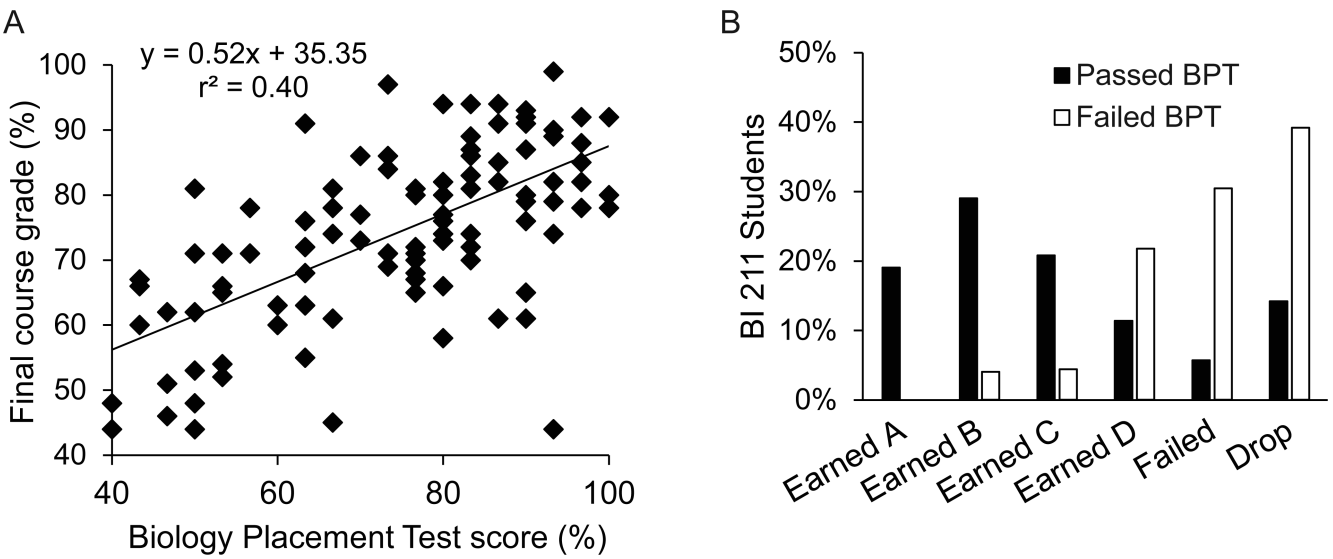


**Figure 1.** Relationship between BPT score and performance in BI 211 in 2012. **(A)** Final course grade vs. BPT score for students who completed all course examinations. BPT and course grade were significantly correlated. **(B)** Assigned grades of students grouped by whether or not they passed the BPT. The grade distributions of students who passed and failed the BPT were significantly different.

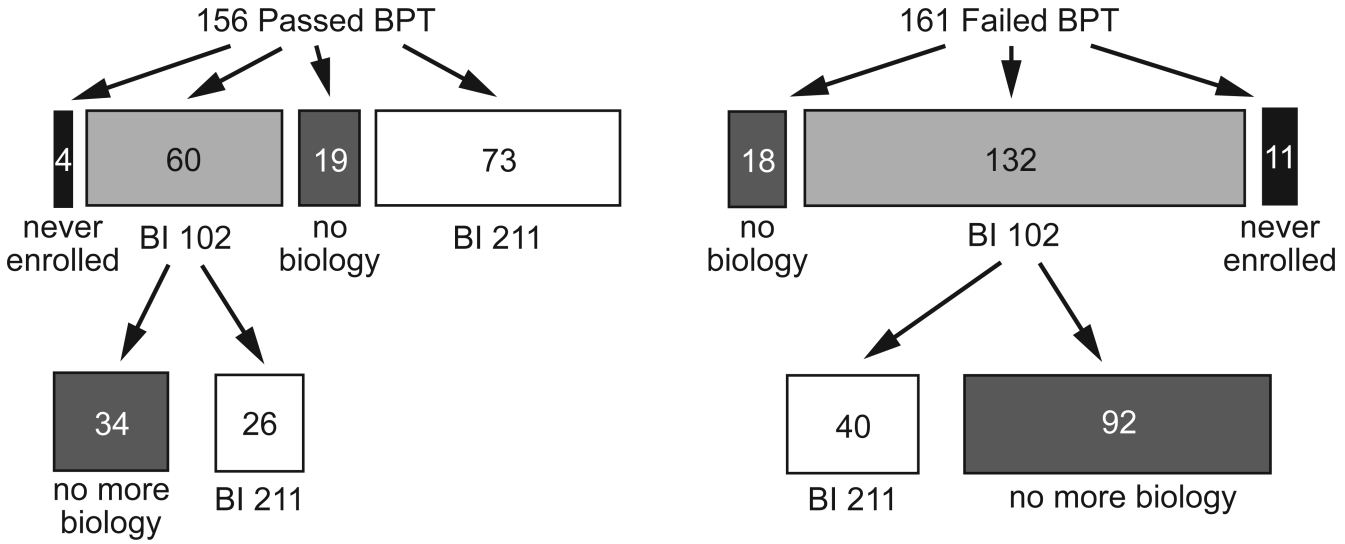


**Figure 2.** Fate of students after passing or failing the BPT. Students categorized as "never enrolled" did not take any classes at WOU.

in BI 211 or BI 102. Because 70 percent of the 2012 cohort reported completing a non-majors biology or chemistry course prior to enrolling in BI 211, we also decided to accept A or B grades in BI 102 as an alternative pre-requisite. This decision was made in part to assuage administrative concerns about reducing roadblocks for transfer students. About 80 percent of students took the BPT during our summer advising and registration (SOAR) session, receiving in-person advising by Biology Department faculty. Our Academic Advising & Learning Center office administers ad hoc drop-in testing during Fall and Spring terms, including managing retake requests (students may retake the BPT after 30 days). About half of all BI 211 students take the BPT; most (75%) take BI 211 after earning an A or B in BI 102, a third of those after failing the BPT.

Between 2013 and 2015, 317 students took the BPT, their one-year course fate summarized in Figure 2. Approximately half (156) of all students who took the BPT passed: 73 took BI 211, 60 elected to take BI 102 first (with less than half going on to BI 211), 19 did not continue in any biology, and 4 canceled enrollment at WOU. The other half of students (161) did not pass the BPT: 132 elected to take BI 102 (with 40 going on to BI 211, but 92 electing not to continue in any biology), 18 did not continue in any biology, and 11 canceled enrollment.

## Enrollment Trends

Based on comparing BI 211 enrollment data with the sizes of incoming freshman classes during pre-BPT years, we estimate that implementing the placement test decreased total BI 211 enrollment by 35–40 students per year (Figure 3A). As reported, though, 192 students enrolled in BI 102 after taking the BPT. Therefore, although BI 211 enrollment decreased, those students still enrolled in a biology course at WOU. Based on the relationship between BPT scores and BI 211 performance in 2012, we would have expected about 115 of the 192 students who enrolled in BI 102 to have failed or dropped BI 211. The students that were directed to BI 102 instead of BI 211 took a course that was more manageable for their biology background, was more conceptual and less detail-oriented, and was more likely to result in a passing grade that could be applied to our university general education curriculum requirements.

Prior to implementing the BPT and course pre-requisites benchmarks, the average F/Drop rate in BI 211 was 25 percent (Figure 3B). The average F/Drop rate during the post-benchmark study years was 18 percent. This difference in the number of students who earned an F or dropped BI 211 was statistically significant ($X^2_{0.05,1} = 6.0$, $p < 0.025$). Additionally, 23 students from the 2013 BI 211 cohort are projected to graduate this year, consistent with longstanding graduation numbers in our department (see Course Context section, above). We conclude that adding the BPT and pre-requisites to BI 211 did not decrease enrollment in biology courses at WOU, did not decrease the number of students in the major, and reduced the proportion of students who earned an F or withdrew from BI 211.

Between 2010 and 2015, WOU served an average of 44 percent FGC students among entering freshmen. Although the proportion of FGC among entering freshmen was higher than that in BI 211 (31%), the installation of benchmarks did not have a negative effect on FGC enrollment in this course (Figure 4A); in fact, FGC enrollment in BI 211 increased during all years post-BPT ($X^2_{0.05,1} = 7.9$, $p < 0.005$), despite an overall decline in FGC students among entering freshmen. We then examined whether FGC students were represented at higher rates among the proportion of students failing/dropping BI 211, and found that the FGC student success rate was not different than the overall success rate (Figure 4B; $X^2_{0.05,1} = 0.37$, $p > 0.5$). After the installation of BI 211 benchmarks, URM enrollment increased (Figure 4C; $X^2_{0.05,1} = 5.01$, $p < 0.05$). We next examined whether URM students were represented at higher rates among the proportion of students failing/dropping BI 211, and found that the URM student success rate was not different than overall success rate (Fig 4D; $X^2_{0.05,1} = 2.12$, $p > 0.1$).

## Benchmark Access Analysis

We compared access-defined cohorts in terms of success in the course for the three years after benchmark installation (2013–2015), summarized in Figure 5. Between 2013 and 2015, 339 students took BI 211,

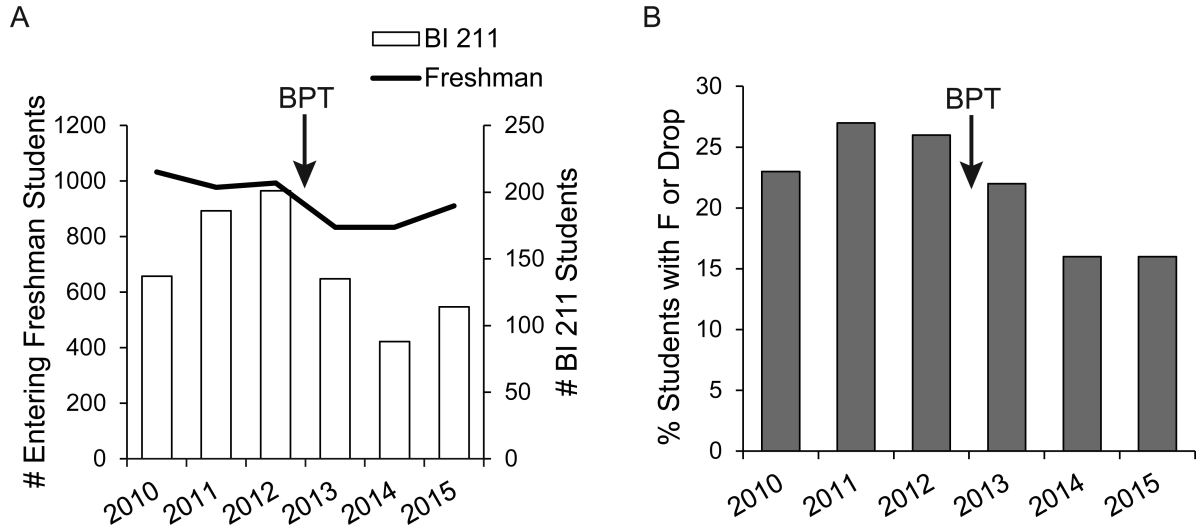


**Figure 3.** Impact of BPT and pre-requisite courses on BI 211. **(A)** Enrollment in BI 211 decreased compared to the number of incoming freshmen at WOU after implementation of the BPT. **(B)** The percentage of students failing or withdrawing from BI 211 decreased after implementation of the BPT.

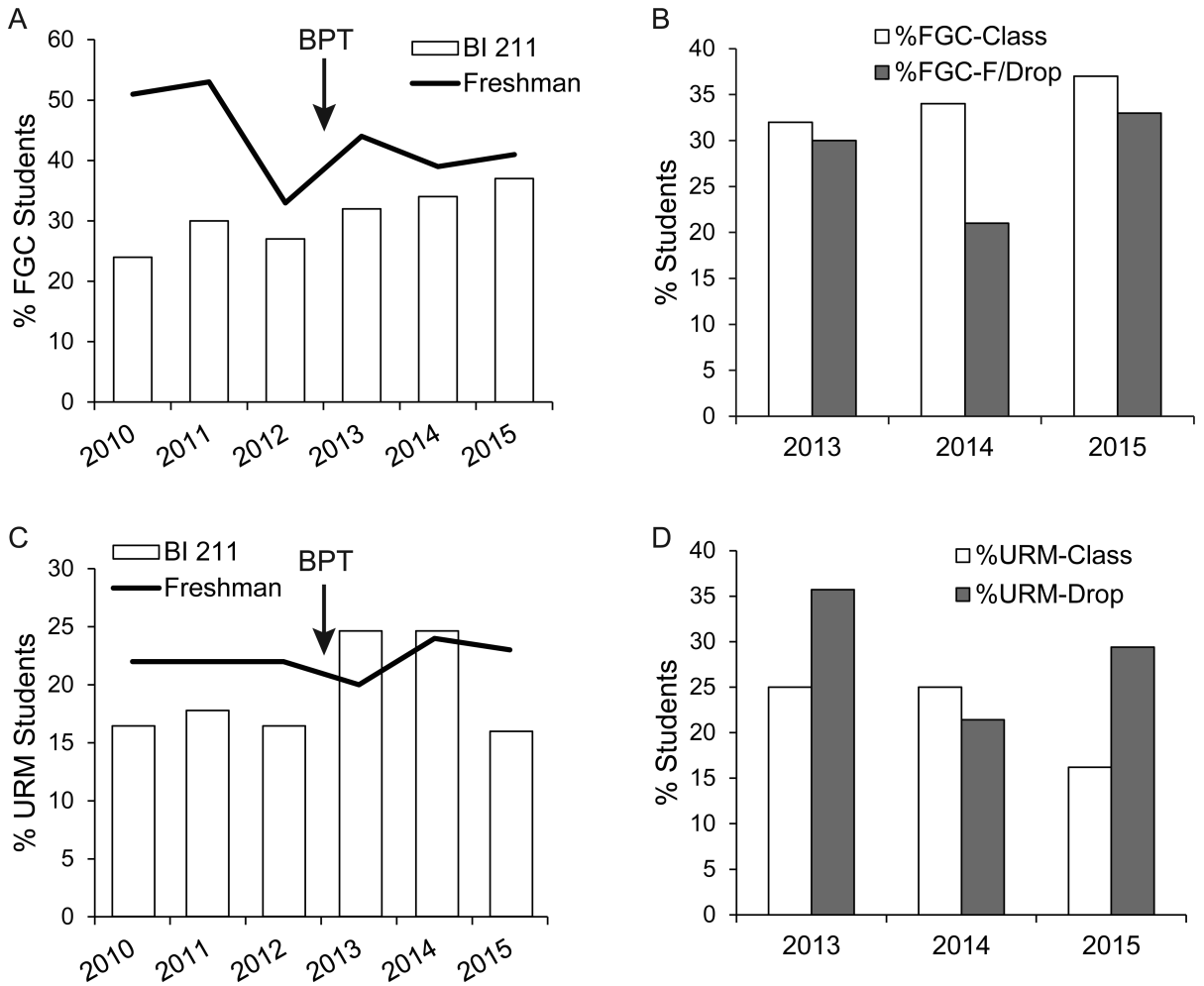


**Figure 4.** Enrollment and success of specific demographic groups. **(A)** The percentage of FGC students in BI 211 and in the freshman class on campus. **(B)** The percentage of students who earned an F/Drop and were FGC students, and the overall percentage of FGC students in BI 211. **(C)** The percentage of URM students in BI 211 and in the freshman class on campus. **(D)** The percentage of students who earned an F/Drop and were URM students, and the overall percentage of URM students in BI 211.

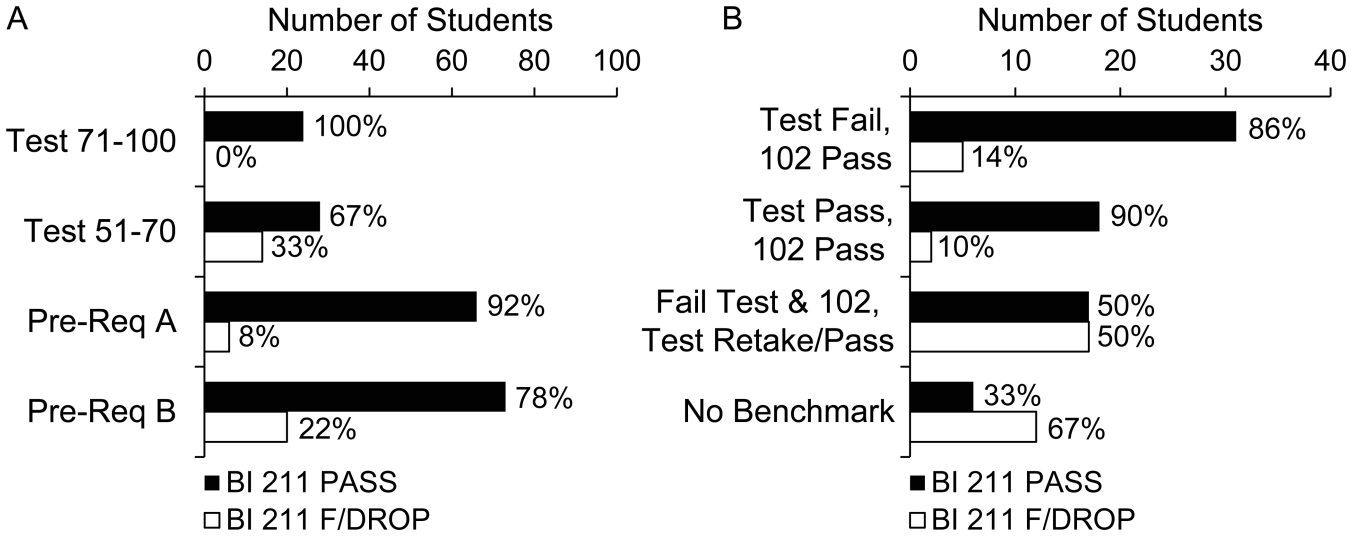


**Figure 5.** Rates of passing BI 211 based on how students entered BI 211 after implementation of the BPT and course pre-requisites. **(A)** Students who entered BI 211 after either passing the BPT or earning an A or B in a prerequisite course. **(B)** Students who enrolled in BI 102 after taking the BPT. For this figure, "failing" BI 102 means the student did not earn an A or B—the prerequisite grade needed to enter BI 211. A small number of students (18 from 2013–15) were enrolled in BI 211 without passing the BPT or BI 102 with an A or B.

with most (75%) using the A/B pre-requisite benchmark—a third of these after failing the BPT. In examining the data further, we also observed that BI 211 students fell into one of two access categories: students who met a benchmark after one attempt (Figure 5A), and students who showed more complicated pathways (Figure 5B). Most students (231 students, 68% cohort) passed a benchmark and proceeded in one step to BI 211. Within this group, the most successful sub-cohorts earned higher scores (> 71) on the BPT or As in the pre-requisite course. Nearly 95 percent of higher-scoring groups passed BI 211. The least successful sub-cohort earned 51–70 on the placement test, with 33 percent failing/dropping BI 211.

In terms of the "complicated pathway" cohort (108 students), over half of these students (56 students) took both the BPT and then earned an A or B in BI 102. This group was overall successful in BI 211, with 88 percent passing. The most complicated group (34 students), failed the BPT, did not pass BI 102 with an A or B, and then retook the BPT, passing it on the second try (usually immediately after finishing BI 102). Only 50 percent of these students passed BI 211. When after-the-fact researching other program BPT policies, we noted some (e.g., Chapel Hill) had explicit policies against taking the BPT after any grades were established in pre-requisite coursework. Finally, try as we might to screen access, some students (18) took BI 211 with no benchmark. Most did not earn an A or B in BI 102 after signing up for BI 211 (an unfortunate aspect of our registration system/timing). In other cases, advising or transcript review errors occurred. That 67 percent of this sub-cohort failed BI 211 is testimony to the power of careful, thoughtful advising when it comes to success in this important course—and, possibly, the power of denial (Williams et al., 2013).

## ○ Discussion

Like several other Biology Departments, we developed a diagnostic BPT that is used to determine readiness for majors-level introductory biology. We did so after deploying active learning strategies that failed to reach F/Drop students who earned low scores on pre-course assessments and had chronic problems with attendance and study skills. Our BPT questions were intentionally aligned with Oregon Department of Education standards for middle and high school science. We developed our BPT in partnership with campus administrators and the Academic Advising & Learning Center, partnerships that are essential to making this process work effectively. Based on our survey of BPTs and validation studies, this report represents the first formal study about diagnostic BPTs and their effect on enrollment and success.

Students who passed our BPT demonstrated significantly higher pass rates in BI 211. That said, half of all BPT takers do not pass, and the majority of these students ultimately left biology. Although these challenging findings may not be surprising for many programs, it is important to remember that many such students ultimately benefit because they earned higher grades in BI 102 (approximately 90% pass rate, data not shown) and could make earlier decisions to pursue different paths, as opposed to earning lower, failing grades that could more significantly harm their scholarship or financial aid situation.

It is also important to note that about 70 percent of BI 211 students interested in a biology major at our institution state they want to become health professionals but often do not understand what that entails in terms of science training. We hypothesize that this disconnect represents much of the observed BPT attrition. Indeed, faculty observations from SOAR sessions anecdotally suggest that some students avoid general biology in high school in favor of specialty courses (e.g., Anatomy & Physiology) because they perceive those as more relevant to their career goals; others report avoiding AP Biology because this course is perceived as harder and more threatening to their GPA. Unfortunately, our institution does not electronically archive or provide high school information for advising; this was, in fact, another reason we chose to develop

our own BPT assessment approach. In terms of BPT data, it is worth mentioning that we did observe different BPT averages during the 2012 trial run (73%) vs. the 2013–2015 implementation years (50%). We believe this was due to the fact that the 2012 cohort represented students who had already enrolled in BI 211 after summer advising, vs. the 2013–2015 BPT cohort, which represent students who took the test at SOAR prior to engaging with advisors.

Although enrollment pressures cannot be ignored, our data strongly support that the BPT and companion benchmarks have increased student success despite enrollment decreases in BI 211, some of which are offset by would-be majors taking BI 102 instead. Moreover, these benchmarks have not affected FGC or URM enrollment in BI 211, nor have they introduced demographic biases among F/Drop students in this course. These observations directly contrast with at least one other study suggesting that certain demographic groups fare more poorly in college biology (Tai et al., 2006). Early retention of these important student cohorts is profoundly important to sustain scientific literacy, represent diversity, and provide fair scientific opportunities in the United States. We recognize that this study was limited to examining only the first step in earning a biology degree, and therefore the next phase of this project, underway at this time, is using this ongoing, evidence-based approach to examine the long-term pathways of students who begin in BI 211.

Regardless of design, BPTs represent an important link between secondary science education and the college/university experience in biology. Secondary science educators provide crucial introductory biology education that can provide qualified students with important opportunities to test out of expensive coursework, moving them closer to their goals. That said, secondary science educators should be emphasizing general introductory biology, particularly foundational knowledge in biological molecules, cells, and genetics, given that these topics remain key early benchmarks. The temptation to focus on specialty courses or topics may be attractive to many students, but they do not provide a substitute for foundation knowledge, whether in terms of testing into or out of first-year coursework for allied health or biology majors. The more cross-institutional communication and advising with respect to providing all students with effective foundation coursework in biology, the better students will fare in higher education and biology careers.

## ○ Acknowledgments

We would like to gratefully thank and acknowledge Max Chartier, WOU Data Architect/Institutional Research Analyst, for supplying data on campus-wide enrollment and demographics. We would also like to thank Arlene Courtney, WOU Department Head of Chemistry, for informative discussions about the American Chemical Society and Chemistry Placement Testing.

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*ASM-CUE research posters linked at www.wou.edu/~boomers/boomer.html

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*The mission of the NABT BioClub is to recruit, support, nurture, and promote students who have an interest in biological sciences for personal reasons, academic preparation, the betterment of society, and possible career opportunities by providing guidance, resources, and activities to meet these goals.*

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