A Biology Course for the Less-Than-Prepared Prospective Biology Major

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Abstract: Many undergraduate institutions are dealing with less-than-prepared students entering the biology major. When the biology department at College of Notre Dame of Maryland analyzed data from five past cohorts of prospective biology majors, it was evident that there was a significant correlation between their success in the introductory course in the major and their math SAT score (Spearman's rho = 0.058; $p < 0.001$). Based on these results, the biology department developed a preparatory course for students whose MSAT score was below a prescribed cutoff value and stipulated that a student must pass this preparatory course with a grade of at least C+ to take the introductory course. For the first four cohorts (n=93), 95.9% of those who enrolled in the introductory course in the semester following the preparatory course received a grade of at least C. For these students, there was no correlation between their grade in the introductory course and their MSAT score. This paper describes how the department determines which students take the preparatory course, explains the design of the course curriculum and assessment within the course, and presents an analysis of the first four cohorts of students to progress through the course.

Keywords: curriculum, SAT, MSAT, preparatory course

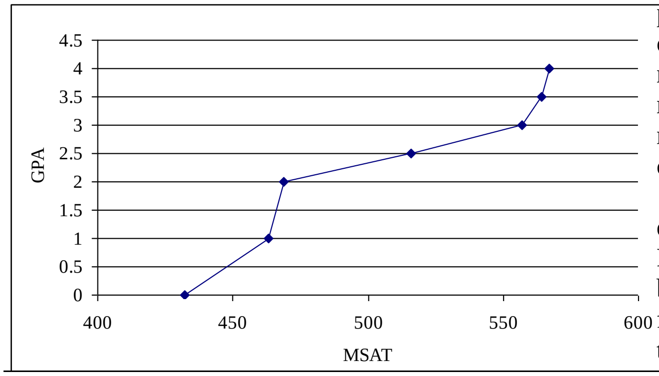
Introduction

Each fall semester, about two-fifths of the incoming first-year students at College of Notre Dame of Maryland, a liberal arts college for women, envision themselves as biology majors. As the instructor of the introductory biology course, I often found a mismatch between students' preparation for college biology and the demands of the undergraduate biology curriculum. Over the years, the biology department made several attempts to address this situation by incorporating workshops into the introductory course and by suggesting that students whom they judged to be less-than-prepared defer taking the introductory course until the spring semester. Neither strategy, however, enabled students to complete the introductory course in a manner that prepared her to be successful in subsequent biology courses. Therefore, in 2004, the biology department addressed the issue head-on by introducing a specific course for less-than-prepared students. It was our hope that each student taking that course would either (1) continue with her plans to major in biology and take the introductory course, but be more informed about both the nature of the discipline she was choosing and about her strengths and weaknesses as a student of that discipline; or (2) realize that the biology major did not match her academic strengths, complete her general education science requirement and look for a more suitable major. This paper describes how the department determines which students take the preparatory course, explains the design of the course curriculum and assessment, and presents an analysis of the first four cohorts of students to complete the course.

Placement of Students into the Preparatory Course

Guided by informal observation of students in the introductory course (BIO 111: Fundamentals of Biology) over numerous semesters, we conducted a formal statistical analysis of student grades in that course from five consecutive semesters. This comparison revealed a significant predictive relationship between MSAT score and a student's performance in BIO 111 (Figure 1). The Spearman's rho (non-parametric correlation) was 0.58, which is highly significant ($p<0.001$). There was, on the other hand, no significant predictive relationship between a student's performance in the introductory course and either verbal SAT score, overall high school GPA, or high school biology GPA. Our finding was later bolstered by an NSTA report (2004) that only 26% of students who took the ACT achieved on the math component a score that predicted their ability to earn a grade of C or better in a college biology course. An MSAT score, which has "floated" around 510, was set as the dividing line between students placed into the introductory course (BIO 111) and the preparatory course (BIO 110:Exploring Concepts in Biology).

Figure 1. Relationship between GPA earned in an introductory course and MSAT for five semesters of students (n=71)



Foundational Principles

The course for less-than-prepared potential biology majors is built on a foundation of five principles, each of which is substantiated either by educational literature (Mayer, 2003) or by the experience of students who had been enrolled in BIO 111 in prior semesters. First, research (Seymour & Hewitt, 1997) suggests that one of the greatest difficulties encountered by students in the sciences is trying to catch up with course material with which they have little or no prior knowledge while they keep up with the steady progress of the course into new subject matter. BIO 110, therefore, comprises six units[1] which, while not completely independent of each other, are not developed sequentially. This course structure enables a student who does not succeed academically in the first unit of the course to start fresh on the second, with no need to catch up and keep up at the same time. The 6-unit design also enables the biology department to address a second principle—the need to broaden the rather limited biological background (Uno & Bybee, 1994) of incoming students. Although two-thirds of students in BIO 111 regularly report that they have taken at least one biology course in high school beyond general biology, in almost half of the cases the course is Anatomy/Physiology. Therefore, the 6-unit design opens a window for students on areas of the discipline with which they might not be familiar. Third, many first-year students report that they did not realize that biology is a quantitative science like chemistry or physics. Because successful biology students recognize the deeply-rooted integration between mathematics and biology (Bialek & Botstein, 2004), BIO 110 is built around a series of biological problems, each of which requires a mathematically developed solution. Fourth, many first-year students tend to be surprised by the time commitment necessary to be a successful biology major, particularly by the demands of the laboratory component of BIO 111. BIO 110, therefore, includes an individual research project to provide students with an on-going major assignment throughout the semester. Because this multi-step assignment is conducted by students outside of class time, it challenges their time management skills.

The final principle of BIO 110 is strategy development (Paris, Lipson, & Wixson, 1983, p. 296). Previous discussion with students enrolled in BIO 111, both in *ad hoc* individual advising settings and in more formally structured focus groups, suggested that the targeted students in BIO 110 have a limited set of strategies. Students explained that they had encountered difficulty applying mathematical principles, reading scientific text, writing about biological concepts, and studying. The purpose of BIO 110 is to provide students with daily opportunities to consider the declarative, procedural and conditional knowledge that underlie good strategy development (Simpson & Nist, 2000) in the framework of six biology units.

Math Strategies

Students who must be placed in a remedial mathematics course in college are considered at-risk for college completion (Berenson, Carter, & Norwood, 1992). Although the students for whom BIO 110 was designed do not require remedial math, it appears that their math performance compromises their ability to successfully complete BIO 111. Because these students have little appreciation for the complex connections between biology and mathematics (Jungck, 2005), our intent was to present a biology course in which students can't separate biology from mathematics. Learning math with understanding (Carpenter & Lehrer, 1999) emerges from five types of mental activity. Students must construct relationships between new mathematical ideas and their prior knowledge, extend their mathematical knowledge in ways that clarify its application, consciously draw connections between their prior knowledge and the knowledge they are presently acquiring, and, finally, make their mathematical knowledge their own. To facilitate these types of thinking, BIO 110 is organized around math-based activities which are not mathematically sophisticated, but whose completion is necessary for building an understanding of biology. For example, in

[1] The six units are anatomy, botany, ecology, evolution, genetics, and microbiology. Specific information about the content of these units will be supplied by the author on request.

the botany unit, students work with two sets of oak leaves, deep-lobed and shallow-lobed. They develop a method to determine what percentage of the total outlined area of each set of oak leaves is taken up by interlobe spaces,[2] determine the number of stomata per mm^2 from nail polish casts, and conduct t tests to compare area and stomata values for the two sets of leaves. Then, based on an understanding of photosynthesis developed through use of models, they hypothesize the location of the two types of leaf in a single tree.

Because most of the students in BIO 110 are more familiar with the transmission model of teaching/learning mathematics (De Corte, Verschaffel, & Op'T Eynde, 1999), students are not merely presented with the necessary mathematical procedures; they are helped to develop them and are required to explain mathematical procedures both while they are carrying out the tasks and after they have completed them. Being asked questions like "What are you doing?" and "Why are you doing that?" on a regular basis helps students to realize they should be asking these questions of themselves. Moreover, when students work on a task that they find interesting and when they are expected to explain the math that they have utilized to solve the task, "they own that knowledge, stay interested in the mathematics, and do not fear working on problems in new contexts" (Lajoie, 1999, p. 131). The generative nature of this type of instruction in BIO 110 is borne out in the final unit of the course, in the study of a biomechanical model of a foot (Glase, Zimmerman, & Brown, 1981). Whereas students were hampered by mathematical applications earlier in the semester, at the end of the semester they comfortably and capably use math to determine whether the foot is designed for speed or for force.

Reading Strategies

Students enter college from secondary schools in which teachers assign them a total of 12 pages of textbook reading each day (Donahue, Voelkl, Campbell, & Mazzco, 1998). Moreover, many of these students are passive readers for whom it is more important to get pages read than to understand content (Alexander & Jetton, 2000). In college courses, however, faculty expect students not only to read far more textual information, but to understand and remember it on their own (Simpson & Nist, 1999).

College students can be categorized as either successful or unsuccessful readers based on three factors (Simpson & Nist, 1999): how much they think that learning a particular subject is at least partly their responsibility; how much they distinguish in their reading between concepts that they understand and those they don't, and then alter their reading based on that distinction; and how much they recognize the difference in reading requirements across and within disciplines and modify their strategies accordingly. Part of the transformation of unsuccessful readers into successful ones involves "nudging" them (Simpson & Nist, 1999) into thinking about their theories and practice of reading biology by introducing reading strategies that include both cognitive and metacognitive processes embedded in the context of biology.

BIO 110 concentrates on three types of biological literature (Pugh, Pawan, & Antommarchi, 2000)—the textbook, primary research literature, and trade books—and presents strategies that are inherent in reading each type. Strategies for reading the textbook focus on how to translate text formatting into conceptual hierarchies and how to read and use textbook diagrams. The second reading focus is primary research articles, the type of biological literature with which students report they have the least familiarity. There is a consensus in practitioner research journals (e.g., Levine, 2001; Muench, 2000) that introducing students to this literature has a positive effect on critical thinking. Each of the six units in BIO 110 culminates in the discussion of a primary research article that ties in with the biological question being considered. For example, in the microbiology unit that focuses on Koch's postulates, the students read Marshall and Warren's (1984) classic report in *The Lancet* of the relationship between stomach ulcers and *Helicobacter* infections. And in the evolution unit, after determining the effect of a severe drought on the finch population on one of the Galapagos Islands by working with a website that presents the data of Peter and Rosemary Grant (Bonner, 2006), students read "Intense natural selection in a population of Darwin's finches (Geospizinae) in the Galapagos," Boag and Grant's (1981) report in *Science* of the effects of that same event. Before the discussion of each primary research article, students are given a set of guide questions to prepare in small groups outside of class. These question sets become less detailed as the semester progresses. The third reading focus in BIO 110 is trade literature that provides students with a window on biology-based careers other than medicine. Students in BIO 110 are presented with a list of trade books, all of which are kept on 1-week reserve in the library. Each book describes the work of a biologist in a particular field, for example forensic anthropology,

[2] Students cut out photocopies of leaves that are pasted onto poster board. They are led to develop a method by which they can set up a proportion between the mass of $10cm^2$ of paper/poster board and their cut out leaves to determine area.

epidemiology, forensic entomology, conservation genetics, and tree canopy research. To avoid having the assignment feel like a middle school book report, the student is required for each book selected to develop a sequence of courses (in and out of the biology major) that she might take at College of Notre Dame to prepare her for further study in that area of biology; to investigate on line at least one graduate program that she might enter to further pursue that area of biology after graduation; and to write an essay that presents three reasons why she would or would not enjoy working within that career.

Writing Strategies

Research suggests that the goal of most high school students in their writing is to compose single sentences that convince the teacher that they understand what they have learned (Sitko, 1998). Rather than functioning as "knowledge-transformers" (Ferrari, Bouffard, & Rainville, 1998), they perform as "knowledge-tellers." This is a critical deficiency because people who can't write effectively usually can't carry out effective science (Moore, 1994). BIO 110, therefore, provides students with numerous opportunities to make their thinking visible (Ellis, 2004). Four main types of writing assignments are described here: Learning Logs, follow-up assignments to class activities, reflection papers, and the Independent Research Project (IRP).

Learning Logs require students to look back on the class period that just concluded and think about what they did in class that day, what they learned, how the content of the day's class connects with what they already know, how they will study the material, and what they don't understand. Students e-mail the instructor the answers to these six key questions by midnight of the day before which they have the next class meeting. Learning Logs are a low-stakes writing assignment, assessed as $\checkmark^-$, $\checkmark$, $\checkmark^+$.

After completing an activity, students are usually required to write a follow-up summary of the procedures or the outcome, formatted as either the Materials and Methods section or the Results section of a laboratory report. Each of the six units includes two or three follow-up summaries. Students are aided in the writing of this type of assignment by the website LabWrite, http://labwrite.ncsu.edu/www/. These middle-stakes writing assignments are assessed for how well they follow the laboratory report format.

Reflection papers constitute a major form of high-stakes writing assignment in the course. At the conclusion of each unit, students answer a series of questions, similarly structured for each unit, but specifically based on activities that were carried out and primary literature that was read during the unit.

The Independent Research Project (IRP) (Walvoord & McCarthy, 1990) is a second form of high-stakes writing embedded in BIO 110. For the IRP, each student selects two brands of a consumer product, chooses appropriate operational variables, defines each variable, designs and conducts an experiment by which each variable can be measured quantitatively, conducts a statistical analysis of the data, and graphs in Excel the data generated by her experimental procedures. The writing of the IRP is carried out in stages in the style presented in LabWrite.

Study Strategies

Research with first-year undergraduates (Van Etten, Pressley, Freebern, & Echevarria, 1998) suggests that many enter college expecting that the same study strategies that carried them through high school—memorization and last-minute preparation for tests—will be sufficient for success in college. Therefore, introducing students to a more diverse set of strategies is another focus of BIO 110. After each new topic is discussed in class, a second conversation develops around how that particular topic might be studied by students on their own or in study groups. Students are given opportunities to explain the declarative, procedural, and conditional knowledge on which their strategies are built and by which their understanding is assessed. "How do you know that you know this?" is the question that arises daily. These discussions continue throughout the semester, because changes in students' metacognition require extended periods of time (Simpson & Nist, 2000).

Course Implementation

Before first-year student course registration, students who intend to major in biology are identified from their college application materials. MSAT scores are reviewed and recommendations are made on a form that is placed in each student's advising folder. When the student meets her academic advisor to select her courses, the placement information is readily available.

The class size for BIO 110 is initially set at 18, but is adjusted to include all students who need to enroll. It has never exceeded 25 students. Three 2-hour classes a week permit a mixture of lecture, laboratory exercises, learning activities, and discussion. Because a great portion of class time is spent by students working on activities in small groups, older biology majors are trained to act as teaching assistants.[3]

[3] Because many of these students plan to work as TAs in graduate school, this provides them with invaluable training.

Assessing Student Progress

Assessment of learning in BIO 110 is carried out by the students and by the instructor. At the beginning of each unit, students take a short survey of their prior knowledge of the content of the unit that frequently indicates that students apparently either have a cursory understanding of the biological content or recall very little of the material they learned in high school. As part of each reflection paper, students assess how their understanding developed by comparing their prior knowledge of a concept at the beginning of the unit to their understanding at the completion. At the end of the semester, students are asked to assess themselves regarding the eight skill-based objectives of BIO 110 and choose three in which they think they made the greatest progress. The skills most frequently selected are reading and analyzing primary biological literature; studying various types of biological concepts and assessing understanding of a concept; and designing and conducting a scientific investigation.

Daily Learning Logs, which provide the most helpful day-to-day feedback about student progress through the course, are assessed as $\checkmark^{-}$, $\checkmark$, $\checkmark^{+}$. Because Learning Logs are returned to students at the class meeting that immediately follows the meeting on which they reflected, they provide immediate feedback to students. In addition, frequently the content of the previous meeting's Learning Log serve as the springboard for the subsequent class.

Information about student progress is also derived from reflection papers, the open-book formal assessment given at the end of each unit that students complete on their own time. Usually, students' grades on the first reflection paper are low. A student who receives an F on the first reflection paper is offered an opportunity to enter into a contract: the failing grade on her first reflection paper will not be considered in the determination of her final grade if she sets up an appointment to talk about how she is working in the course and if she does not receive a grade below a D on subsequent reflection papers. By the second reflection paper of the semester, almost all students receive a passing grade. Because the same format is used in the rubric for all reflection papers, students can easily map their progress from one unit to the next.

Students' work on the IRP follows a timeline that spreads out the research over the semester. On-going steps in the IRP received extensive commentary, but are assessed Submitted/Not submitted. The final full lab report is evaluated by an extensive rubric that assesses the quality both of the research and of the written report.

Analysis of Students Enrolled in the Preparatory Course

In the history of the first four cohorts enrolled in BIO 110 at College of Notre Dame (2004-2007), 93 students enrolled in the course (Table 1). Eleven of these students withdrew from the course before the end of the semester, four failed, and 78 (95.1%) passed. Fifty-one of these students enrolled in BIO 111 in the semester immediately following BIO 110.[4] Two of these students withdrew from BIO 111, two failed, and 47 (95.9%) passed with an average grade of C+ (75.9%). For these 47 students, there was no significant correlation between their grade in BIO 111 and their MSAT scores; in fact, all of them had an MSAT score that predicted a BIO 111 grade no higher than D (60%). By way of comparison, the average grade earned by students who were immediately placed into BIO 111 during these same four years (2004-2007) was also C+ (75.2%).

[4] In the first year, a grade of C was the prerequisite for enrolling in BIO 111; in subsequent years, the required BIO 110 grade has been C+.

Table 1. Outcome of first four cohorts to progress through BIO 110/ BIO 111 sequence. The numbers in parentheses in the first two columns indicate the number of students initially enrolled in each course. The number of declared, undeclared, and withdrawn students is based on the number of students who completed BIO 110.

Cohort	Passed BIO 110	Passed BIO 111	Declared major in BIO	Declared major in other than BIO	Undeclared	Withdrew from NDM/ LOA
2004-05	20 (24)	9 (11)	5	10	0	5
2005-06	19(24)	14 (14)	6	4	0	9
2006-07	21(25)	15(15)	9	4	0	8
2007-08	19(20)	9(11)	9	4	2	3
Total	78(93)	47(51)	29	22	2	25

We believe that the preparatory course, BIO 110, has achieved both of its intended objectives for less-than-prepared first-year biology students at College of Notre Dame. The skills embedded in the course have been used by some students to move successfully into and through the biology major. Twenty-nine students who statistically would not have even passed BIO 111 became successful biology majors, indistinguishable to instructors in 200-, 300-, and 400-level biology courses from students who were placed immediately into BIO 111. In the biology department's senior seminar course in spring 2008, two of the top three grades were received by students who had been enrolled in BIO 110 as first-year students; a junior biology major who had been enrolled in BIO 110 as a first-year student was accepted into the prestigious Dual-Degree Nursing Program with the Johns Hopkins School of Nursing. The graduating class of 2008 included five biology majors who had taken BIO 110 as first year students. At the time of graduation, their biology/chemistry average GPA was 3.02; their overall average GPA was 3.13. Their average MSAT score when they matriculated at Notre Dame was 470. BIO 110 has also accomplished its second objective: it has offered a positive network in which students can recognize that biology does not match their academic strengths. Twenty-two students who completed BIO 110 switched to a different major, either immediately after taking the course or after successfully completing BIO 111. For these students, however, in contrast to the students before the BIO 110 era, the change of major was not based on feelings of defeat or frustration, but on the realization that biology was not the best match with their academic skills and interests. The graduating class of 2008 also included seven students from the first BIO 110 cohort who completed undergraduate programs other than biology; their average MSAT score at the time of matriculation was 446.

In addition to the hoped-for outcomes of BIO 110, there have also been unanticipated positive effects. Because BIO 111 no longer includes less-than-prepared students, its conceptual rigor has been elevated with the incorporation of primary research literature and problem sets. BIO 110 has also had unanticipated effects on overall retention among all its enrollees. Out of the 78 students who completed the course in the first four years, 71.7% have remained at Notre Dame. This retention rate compares favorably with the national retention rates for students in this category. For all the students who enrolled in BIO 110, the course fulfilled an important role. It provided them with a context in which to evaluate both their abilities as students and the discipline in which they planned to focus; it also provided them with the necessary scaffolding to achieve success in college regardless of their eventual major.

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Editor's Note

Because of the extra length of this online edition of *Bioscene*, I have not written an editorial. However, I would like to encourage readers to submit cover art and articles for *Bioscene.* Moveover, the annual fall meeting will be held October 9-10, 2009, at Rockhurst University in Kansas City, MO. Further details will be made available at our website www.acube.org. The next issue for *Bioscene* will be the December print issue. Also, at the website are the forms for becoming a member of ACUBE. Forms and payments are to be sent to our secretary Tom Davis.

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