Nonideal Placement of Nonmajors in Biology Major and Allied Health Courses Results in Poor Performance and Higher Attrition Rates

By Farshad Tamari, Mary Dawson, and Ivan Shun Ho

Nonideal enrollment of nonbiology majors into biology majors courses serves as an impediment to academic success and negatively impacts rates of college course completion. In this Institutional Review Board (IRB)-approved investigation, we examine student success, as measured by student grades and course completion rates, for nonbiology majors who nonideally enroll in biology majors and allied health courses. We compare their achievements with biology majors and allied health students enrolled in courses specifically designed for biology majors and those who pursue allied health paths, and with nonbiology majors who appropriately take biology courses designed for nonmajors. We show that under these circumstances, nonmajors perform worse in majors and allied health courses compared to their peers who enroll in the correct courses. In addition, our study shows that nonmajors have significantly higher attrition rates when enrolled in biology majors and allied health courses. Strategies to guide students and prevent nonideal course registration are discussed in the context of the Achieving the Dream (AtD) initiative, which uses a data-driven approach.

College and university academic departments typically offer separate courses for their majors and nonmajors. Courses for nonmajors tend to be stand-alone and offer overviews of topics deemed most relevant and important by the departments that offer them (Klymkowsky, 2005). The Department of Biological Sciences at Kingsborough Community College (KCC) similarly offers different introductory courses with a laboratory component for biology nonmajors (NM) and majors (M): BIO33 is a stand-alone introductory course for nonmajors, BIO13 and BIO14 are two sequential introductory biology courses for biology majors, and BIO11 and BIO12 are two-semester human anatomy and physiology courses for students who want to pursue allied health professions. Nonmajors should enroll in BIO33 for fulfilling their laboratory degree requirement. KCC does not have any gating mechanism in its registration process to prevent nonmajors from taking biology majors and allied health courses. Due to limited laboratory space and the greater number of nonmajors, the quantity of sections offered sometimes do not satisfy demands resulting in nonmajors enrolling in majors and allied health courses in error (Figure 1). In addition, there are several factors that may prevent nonmajors students from registering into the appropriate course including:

1. Errors in advisement (e.g., student advisement to fulfill full-time student status or to speed up graduation).
2. Students register into courses around their own work/life schedules and not based on BIO33 section availability.
3. Registering in classes without consulting with an academic advisor.
4. Registering in a course that has the lowest course number (BIO11).

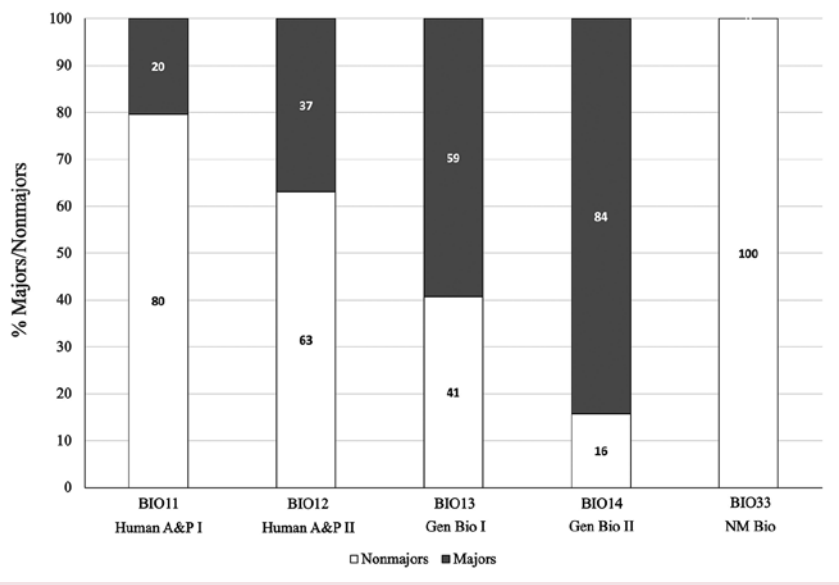
Not surprisingly, very often in BIO13 and BIO11, nonmajors find the course content overwhelming due to the in-depth nature and amount of materials covered in these majors and allied health courses. This results in high failure and withdrawal (attrition) rates (Table 1).

Various studies indicate that active learning and inquiry-based learning improved student learning in both science and nonscience majors (Cotner, Loper, Walker, & Brooks, 2013; Freeman, et al., 2014; Connell, Donovan, & Chambers, 2016; Gardner, Bonner, Landin, Ferzli, & Shea, 2016; Tamari

and Ho, 2019). Despite these efforts in reforming courses to increase the magnitude of student learning, non-STEM majors usually do not take science courses simply to quench their thirst for knowledge, nor to get better positions in the workforce; they take these courses because the system says they have to (Smith, Gould, & Jones, 2004). In addition, survey data from a four-year university has shown that non-STEM majors tend to be less confident about succeeding in science courses and they do not think sciences are connected to any nonscience fields such as history, literature, economics, and art (Fenollar, Román, & Cuestas, 2007; Cotner, Thompson, & Wright, 2017). Therefore, non-STEM majors may not have the motivation, confidence, nor the necessary background to support them through a STEM majors course if they are nonideally enrolled in one. Although as science educators we would like to train more scientists and engineers, non-STEM students will more likely have career path and positions impacting policy change in science-related issues, such as climate change, vaccination effort (note current measles outbreak), and scientific research funding. Therefore, we cannot neglect the negative impact of putting non-STEM students in majors courses, as this may cause them to be more science averse (Cotner et al., 2017), nor can we ignore the academic cost of nonmajors enrolling in a majors biology course. For example, Knight and Smith (2010) found that nonmajors were outperformed by majors in content assessments, were less motivated to do well in the course, and walked away with less content knowledge than their majors peers in a genetics course. Knight and Smith suggested that biology courses should focus on interactive strategies that emphasize the applications of biology for nonmajors.

FIGURE 1

Nonmajors and majors enrollment distribution amongst different biology courses. BIO11 = Human Anatomy and Physiology Part I; BIO12 = Human Anatomy and Physiology Part II; BIO13 = General Biology Part I for majors; BIO14 = General Biology Part II for majors; BIO33 = Biology for nonmajors. Note: BIO11 and BIO12 are allied health courses.



In this study, we collected student performance summative data for biology majors and nonmajors (see Methods for categorization) who enrolled in specific sections of BIO11, BIO12 (allied health), BIO13, BIO14 (majors courses), and BIO33 (nonmajors course) from 2015 to 2018. Because nonmajors may not have the background nor the motivation to fully comprehend the in-depth majors and allied health course content (Smith et al., 2019), we hypothesize that nonmajors would not perform well in BIO11, BIO12, BIO13, or BIO14 compared to biology majors. We also hypothesize that nonmajors who appropriately enroll in BIO33 perform better compared to the nonmajors who nonideally enroll in allied health (BIO11 and BIO12) and biology majors courses (BIO13 and BIO14).

Methods

Institutional Review Board approval and student composition

The study was approved by the City University of New York's Integrated University IRB (approval number: #2018-0536). KCC is a part of the City University of New York (CUNY), which serves 274,906 students (Fall 2018). KCC served between 10,506 and 12,847 students annually between 2015 and 2018. In the same time period the biology department served between 646 and 834 majors and 281 and 450 nonmajors (data from KCC Institutional Effectiveness). In this study we refer to students who intend to attain an associate degree in biology as biol-

ogy majors (M). We consider any students who are not in pursuit of a biology degree, but are taking nonmajors biology courses to satisfy their program degree requirement, as nonmajors (NM). The majority of these students are liberal arts majors.

Data collection

Student performance data were collected from multiple sections of BIO11, BIO12, BIO13, BIO14, and BIO33 from 2015 to 2018. For ease of clarity, BIO11, 12, 13, and 14 are collectively referred to as majors courses, even though BIO11 and 12 are designed for students who plan to pursue allied health professions. All data analyses use separate treatment of courses, not cumulative data, across the four courses previously mentioned. The performance data included laboratory, lecture, and overall course averages analyzed as percentages, as well as typical letter grades assigned. As the analysis of data from lab, lecture, and final course average yielded the same results, we only present and compare final course averages. We also analyzed letter grades for students completing a course. Students who completed the courses received final grades of A^+, A, A^- (pooled as A), B^+, B, B^- (pooled as B), C^+, C, C^- (pooled as C) and D^+, D (pooled as D), and F. For students that did not complete a course, the following letter grades are assigned: Withdrawal (W), never attended (WN), unofficial withdrawal (WU), and incomplete (INC). Students who officially withdraw from the course receive a W, those who register but never attend the course receive a WN, those who stop attending with a failing course average receive a WU, and the ones who stop attending with a passing course average receive an INC. The latter group of grades are considered as a reflection of attrition and are referred to as such (Table 1).

Data analysis

Data for enrollment were compiled using Microsoft Excel (2016) and converted to percent enrollment (Figure 1). Data for letter grades were summed for nonmajors and majors taking majors, allied health, and nonmajors courses. We analyzed these data by comparing letter grades as percentages for each course (Table 1). To determine whether there existed a statistical difference in student performance between majors and nonmajors in each of the five courses, we performed a one-way analysis of variance (ANOVA) followed by a post-a priori (Tukey) test also as percentages. All statistical analyses used SPSS (V. 24, IBM Analytics).

Results

In this investigation we set out to determine whether nonmajors nonideally taking majors biology courses had higher attrition rates measured through receiving W, WU, WN, and INC grades. We also investigated whether enrollment of nonmajors students into biology majors courses negatively influenced their performance as measured by student grades compared to their peers who took the appropriate nonmajors courses to satisfy their degree completion requirements.

Many students nonideally enroll in biology majors courses

Enrollment of biology majors and nonmajors in the five courses investigated in this study are shown in Figure 1. Of particular interest is enrollment of nonmajors in BIO13, which is designed specifically for those students who major in biological sciences and who plan to take further biology courses such as BIO14. Approximately 41% of students that enroll in BIO13 do not at the time major in biology, and thus are enrolled in this course nonideally. For reasons provided in the discussion, only 16% of students that enroll in BIO14 are not majoring in biology. It is important to note that for BIO11 and BIO12, the number of

TABLE 1

Grades and attrition rates for majors versus nonmajors students in the five biology courses. Note: BIO11 and BIO12 are allied health courses

Course	M/NM	%A	%B	%C	%D	%F	%Attrition
BIO11 (Human A&P I)	NM	7.8	9.3	16.3	8.5	13.2	45.0
	M	12.1	15.2	21.2	12.1	9.1	30.3
BIO12 (Human A&P II)	NM	11.2	12.8	12.3	12.8	11.7	39.1
	M	13.3	19.0	11.4	6.7	15.2	34.3
BIO13 (M Bio I)	NM	2.4	9.4	4.7	11.8	11.8	60.0
	M	16.9	18.5	10.5	13.7	8.9	31.5
BIO14 (M Bio II)	NM	14.3	7.1	14.3	0.0	7.1	57.1
	M	28.0	28.0	17.3	4.0	2.7	20.0
BIO33 (NM Bio)	NM	18.4	31.2	32.7	6.4	1.5	9.9

nonmajors taking the course is even higher (80% and 63% respectively), which at least in part is because allied health students do not need to declare a major.

Higher attrition for nonmajors student who nonideally enroll in biology majors courses

We compared attrition rates, defined as obtaining a W, WU, WN, or INC as a final grade, for both majors and nonmajors taking various courses. Attrition rates for nonmajors students taking majors courses is higher across all majors courses compared to their majors peers. As expected, the highest differentials were observed for BIO13 and BIO14. In BIO13, 60% of nonmajors discontinued with the course compared to only 31% of majors. A lower proportion of nonmajors advance and/or take BIO14, but among those that do, 57% receive grades associated with attrition compared to only 20% for majors. These percentages are much higher compared to attrition rates in the nonmajors course BIO33 which is only 10% (Table 1).

Nonmajors students who nonideally enroll in biology majors courses perform worst

An analysis of grades for nonmajors that take majors courses revealed interesting results. In all cases, relative to their peers, nonmajors received poorer grades than majors students. For example, in BIO13, only 2.3% of nonmajors received an A grade, compared to 17% for majors students. The same is true in BIO14 (14% versus 28%, for nonmajors and majors, respectively). The same pattern is true for B grades; however, the trends seem to equalize for C grades. As expected, the trend reverses for D and F grades, with more nonmajors receiving D and F grades compared to their majors peers (Table 1). Also as expected, nonmajors taking BIO33 do much better than nonmajors taking majors courses in A, B, and C grades, and the pattern completely reverses for D and F grades (Table 1).

Disaggregated comparison of nonmajors student who nonideally enroll in biology majors courses

To better understand performance of nonmajors in majors courses, the data were disaggregated based on course and major. A one-way ANOVA was performed on lab averages, lecture averages, and final grades, but as these comparisons yielded similar results, only those for final grades are presented. We found a statistically significant difference in performance between nonmajors who enroll in majors biology courses with those who enroll in BIO33 for all courses, except BIO14 (Figure 2), with nonmajors showing a lower performance. In addition, when the nonmajors students are compared to their majors peers in each class, they perform statistically worst in BIO13 ($p < 0.001$). This is an important finding because the bulk of nonmajors taking majors courses is found in this course. The lack of significant differences in BIO11, BIO12, and BIO14 is due to different reasons. BIO11 and BIO12 are allied health courses and do not have a requirement for students to major in biology. In BIO14, the lack of statistical difference is due to smaller sample sizes (not many nonmajors take this course as many are screened out in BIO13 and the rest do not need another biology lab course) and the high rate of attrition in its prerequisite BIO13 (Table 1).

Discussion

The negative impact that nonideal enrollment into majors course while being a nonmajors cannot be underestimated. Previous studies already show that nonmajors are less motivated and have less confidence when dealing with the subject matters in science courses (Fenollar et al., 2007; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011). They mostly do not identify themselves as scientific and often have many misconceptions about the field of science and scientists (Cotner et al., 2017). When nonmajors are forced, for whatever reason (see below), to enroll in a majors course—one that is above their level of comprehension and requires much more devotion of time and motivation to succeed in— they tend to perform badly or withdraw as shown by the data presented here. Their failure or withdrawal from these courses may ultimately increase their likelihood to drop out of college and cause them to be science-averse in the future (Smith et al., 2004; Chen, 2013).

Our data support our hypothesis that enrollment of nonmajors in majors courses negatively impacts their performance compared to majors taking the same course for BIO13. This is a significant finding, as the majority of nonmajors who try to satisfy their degree requirements by enrolling into a majors course enroll in BIO13. BIO11 and BIO12 are designed to help students enter the allied health programs at KCC, such as nursing. Students are not required to major in biology to apply and/or be admitted to the nursing program and therefore, the bulk of students in BIO11 and BIO12 are liberal arts majors. This renders the lack of significant difference in performance between the majors and nonmajors less concerning. For BIO14, the lack of difference in performance between

majors and nonmajors may be attributed to a different reason: Only the best of nonmajors advance to BIO14 (in very low numbers, $N = 6$).

A comparison of nonmajors enrolled in BIO33 with nonmajors enrolled in the other four courses reveals a statistically significant difference in all courses except BIO14. This finding reveals the negative consequences for nonmajors taking majors biology courses. More importantly, the same comparison of nonmajors enrolled in BIO33 with majors enrolled in the other four courses reveals no statistical difference in performance with any of the majors enrolled in the majors courses, reflecting the fact that they do as well as majors students in the right course. This is a testament to the fact that the nonmajors should only be taking BIO33, which is designed for nonmajors.

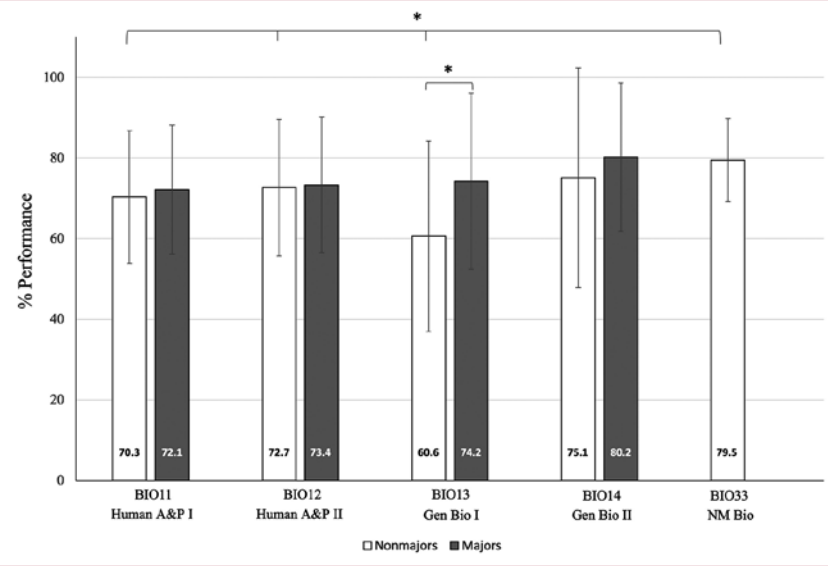
Due to lack of data available on GPA and SAT scores for majors and nonmajors at KCC (most students do not report GPA, and SAT scores are not required for admission at KCC), we could not normalize the data to ensure that the differences observed are not at least in part due to better high school preparation of majors compared to nonmajors. The very limited institutional data that are available on GPA, in many cases with $N < 20$, seem to indicate that there is no significant difference between majors and nonmajors in high school GPA. Interestingly, in three of the six courses for which data were provided, nonmajors had slightly higher GPA and for the other three, the relationship was reversed. KCC does have placement score data available. Majors have slightly better scores for reading (68.3 versus 61.0), writing (45.4 versus 43.5) and Math I (37.9 versus 33.1). While these data were not used in our study to standardize the analyses (because the study design used previously collected anonymized data), this approach is encouraged in cases where an investigator has the opportunity to consent students. Future studies should consider using GPA or SAT, as well as placement test scores to account for nonequivalence between majors and nonmajors (see Theobald and Freeman, 2014, Theobald et al., 2019). It is important to note that due to the dichotomy in student achievements, which is typical in many community and even four-year colleges (Haak, HilleRislambers, Pitre, & Freeman, 2001 reported highest achievement gaps in biology), the use of the above as covariates in statistical analyses may not always be possible.

Student enrollment in nonideal classes typically results in negative consequences among which financial (direct tuition and/or depletion in financial aid) and time costs and degree/graduation delays are obvious. Other consequences of nonideally enrolling in courses are not so obvious. One latent consequence is the negative and quantifiable impact on student performance in each course, which ultimately negatively influences students' GPA, and possibly result in students dropping out of college altogether (Chen, 2013). To prevent nonideal enrollment, institutional safeguards against student enrollment in unsuitable classes should be in place, such as blocks on registration and/or mandatory advisement.

Universities employ various methods for ensuring that nonmajors do not end up in majors courses, but the common variable seems to be registra-

FIGURE 2

Performance comparison between majors and nonmajors amongst different biology courses BIO11 = Human Anatomy and Physiology Part I; BIO12 = Human Anatomy and Physiology Part II; BIO13 = General Biology Part I for majors; BIO14 = General Biology Part II for majors; BIO33 = Biology for nonmajors. Note: BIO11 and BIO12 are allied health courses. * = $p < 0.001$



tion stops embedded in the registration management software. For example, in the Montana State University system, a blanket stop will not allow nonmajors to register for majors biology courses. However, faculty have the authority to override this on an individual basis. In contrast, at Michigan State University, the same stops are in place and faculty may not override the stops. Instead, a department chair's permission is required. At Pennsylvania State University, the stops are in place, but an additional level of safeguarding occurs when advisors check enrollments. In short, most major university systems that handle high volume enrollments have embedded stops that do not allow nonmajors to register for majors courses. At KCC there is no such mechanism. Safeguards at KCC are limited to blocks in registration only if prerequisites are not met, or for academic or financial reasons. Therefore, for reasons previously discussed, many nonmajors nonideally enroll in majors biology courses, despite the fact that in the college catalogue it clearly states which courses are suitable for a particular major. In this paper we propose one or all of the following suggestions to be implemented to help students avoid nonideal enrollment:

1. Provide extensive mandatory advisement with follow-up about appropriateness of courses with properly trained advisors
2. Create blocks to enrollment for nonmajors
3. Provide course numbers in a manner that is clear (for example, lower numbers indicate lower level)
4. Should a nonmajor require to take a majors biology course, adopt a Self-Regulated Learning (SRL) intervention (Smith, Metzger, & Soneral, 2019), which emphasizes metacognition through "training, practice and reflection"; the manifestation of this strategy is highly dependent on motivation, which may not be present for nonmajors taking majors courses.

Alternatively, institutions may offer a pass/fail option for nonmajors who must enroll in majors courses to satisfy degree requirements. Finally, if nonmajors must nonideally enroll in a majors course, a variety of pedagogical strategies can be employed. Among these strategies, the creation of ePortfolio has shown promise through engaging students with the instructor, improving work by scaffolding in low-stakes assignments, which in turn leads to increased submission of and facilitated success in high-stakes assignments (Fuller 2017). Another strategy, which may require a revamping of the course, adopts a learner-centered strategy where the course design, assessment, and other aspects of the curriculum are structured by active student involvement (Hurney, 2012). Active leaning compared to traditional lectures has also been shown as an effective strategy to increase performance and to close achievement gaps (Freeman et al., 2014). ■

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