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Ecology Content in Introductory Biology Courses: a Comparative Analysis

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RESEARCH ON LEARNING

Ecology Content in Introductory Biology Courses: A Comparative Analysis

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Abstract

In recent years the need for ecological literacy and problem solving has increased, but there is no evidence that this need is reflected by increased ecology coverage at institutions of higher education (IHE) across the United States. Because introductory biology courses may serve to direct student interest toward particular biological categories such as ecology, time devoted to topics in these categories within introductory biology courses may be crucial for captivating student interest. In a 2009 survey, members of the National Association of Biology Teachers (NABT) College and University Sections identified 20 topics they considered essential for inclusion in introductory biology courses. The NABT members, acknowledging the importance of ecological concepts, considered two ecological topics essential. The present study evaluated the actual coverage of ecology and other topic categories compared to recommendations and according to location. For this purpose, lecture and lab syllabi were collected from 26 rural, suburban, and urban IHEs from the Mid-Atlantic region. Course content was divided into eight categories, including ecology, and percentages of total lecture and lab time per category were calculated. This actual coverage was compared to the NABT recommendations. Actual coverage of ecology was not significantly different from coverage recommended by the NABT members, whereas cell/molecular/biochemistry and evolution were lower and genetics, development, and taxonomy were higher than recommended. Course content was also compared by location, with no significant effect of institutional location on ecology coverage. We conclude that although students taking introductory biology courses in Mid-Atlantic IHEs are likely to receive the NABT's recommended coverage of ecology instruction regardless of institutional location, actual ecology coverage has not increased, regardless of the increased need for ecological literacy.

Key Words: *Content coverage; ecological literacy; introductory biology; institutional location; NABT recommendations.*

International awareness of the need for ecological literacy to better address pressing environmental issues has been increasing in recent years (York et al., 2003; Hansla et al., 2008). However, support for teaching ecology has been declining at institutions of higher education (IHE) across the United States (Fellman, 2000). Instead many IHEs have started to focus more on molecular biology and biochemistry in the past several decades, despite evidence for the importance of teaching ecological concepts and environmental topics (Fellman, 2000).

Environmental consequences of global climate change, species extinctions, and the increasing human population have created heightened awareness within the scientific community and the media regarding the interactions between humans and world ecosystems. In accordance, textbooks and journals have called for increased ecological literacy and its applications in order to address major problems in ecology (Roberts et al., 2009; Levin, 2010). Educators and the scientific community are therefore essential to teaching and training their cohorts to address these concerns. However, a 2004 survey of biology administrators across the U.S. who evaluated IHE biology core requirements in 2004 compared to 1990 determined increased emphasis on cell/molecular/biochemistry while emphasis on ecology and other historically important categories, including genetics and physiology, decreased (Heppner et al., 1990; Cheesman et al., 2007; Figure 1).

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Introductory biology courses at IHEs are a continuation and expansion of secondary school biology curricula, which in most states incorporate required ecology-related content and application standards. Early courses in IHEs can further focus student interest toward particular categories such as ecology (Heady, 1997; Labov, 2004), and therefore content and structure of introductory biology courses can greatly influence the shaping of future biologists. The expansion of knowledge in the biological sciences over the past decades has demanded that introductory courses in IHEs cover more topics within the same traditional time frame (Coker, 2009; Woodin et al., 2009; Labov et al., 2010; AAAS, 2011). In addition, IHE biology departments are not overseen as rigidly by national or state certification bodies as secondary education institutions, leaving curriculum

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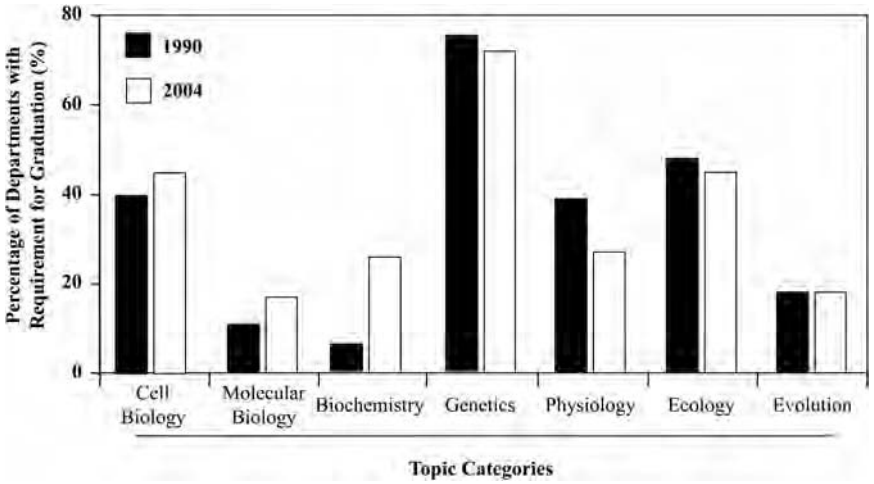

Figure 1. Administrator Surveys: Percentage of biology departments of U.S. institutions of higher education that require specific topic categories in their core curriculum. The figure was composed using data compiled by Heppner et al. (1990) and Chessman et al. (2007). Black bars display coverage in 1990, and white bars display coverage in 2004.

content up to institutional and even faculty discretion (Cheesman et al., 2007). In 2009, members of the Two and Four-Year College and University Sections of the National Association of Biology Teachers (NABT) were surveyed to identify topics they considered "essential" to introductory biology (Gregory et al., 2011), leading to a recommendation that 20 key topics should be included in all introductory biology courses (Figure 2). Topics in evolution, cell/molecular/biochemistry (e.g., DNA and proteins), and physiology (e.g., respiration and membrane transport) were given the highest importance. In addition, ecological topics such as ecosystems, conservation, populations, and communities were considered essential by 74% and 69% of the NABT members, respectively (Figure 2). This indicates that although a declining emphasis on ecology was indicated by biology administrators (Cheesman et al., 2007), NABT members

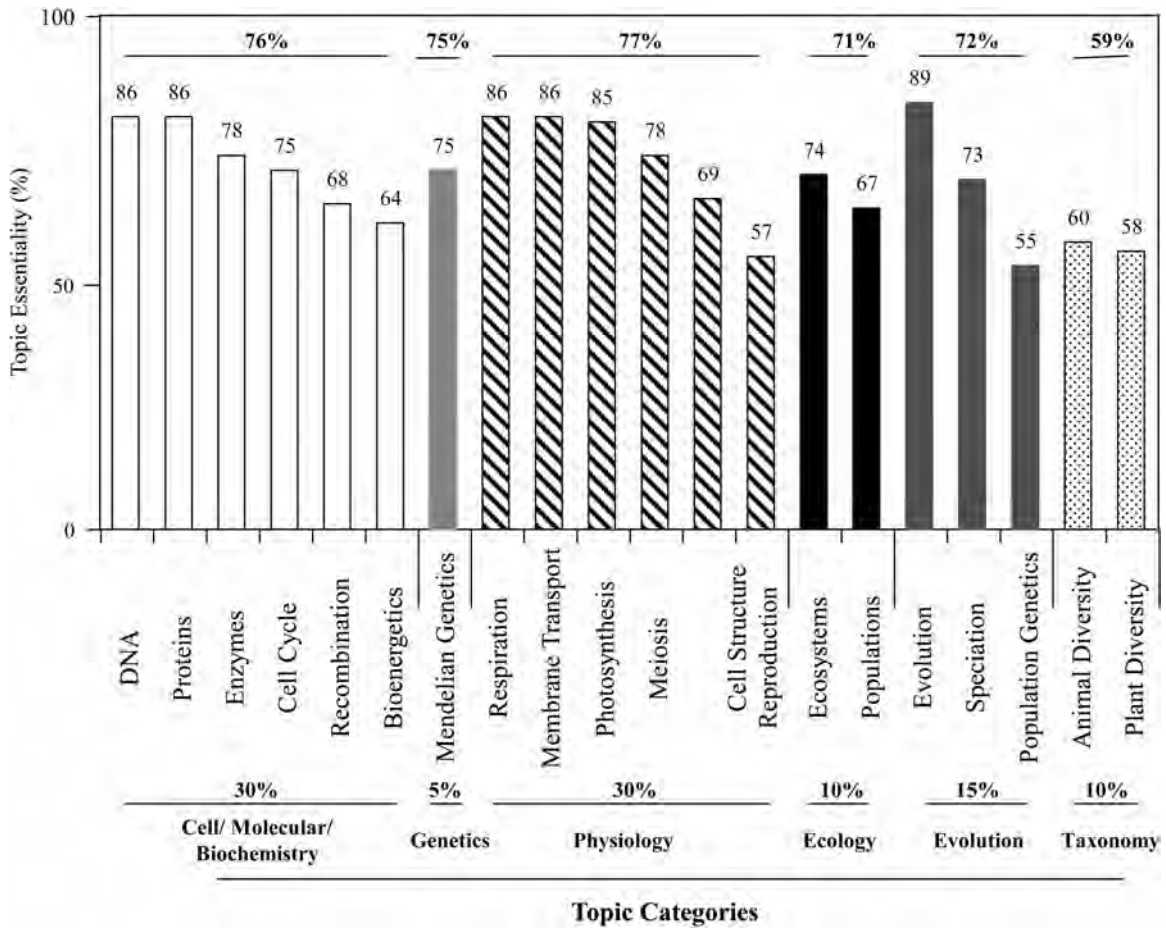

Figure 2. Instructor Survey: Topics identified as "essential" for introductory biology courses by the NABT Two- and Four-Year College and University Sections (Gregory et al., 2011). Data compiled by the authors is identified by the bar graphs, which for the present study were divided into six of the eight topic categories devised for this investigation; white = cell/molecular/biochemistry, light gray = genetics, black striped = physiology, solid black = ecology, dark gray = evolution, black dotted = taxonomy. Percentages above the bar graph are the average importance calculated for each topic category; those below the bar graph display percentages for each category by topic numbers/category compared to total topic numbers considered essential.

affirmed the continued importance of covering ecology at the instructor level (Gregory et al., 2011).

Given the recommendation of including ecology topics in introductory biology courses, the present study sought to (1) determine the proportional coverage of ecological topics compared with other topic categories in a cohort of these courses, (2) determine how the time allocations compared to recently identified NABT essential topic categories (Gregory et al., 2011), and (3) identify whether location plays a role in topic coverage. While previous studies of introductory biology curricula have relied on administrator or instructor surveys (Heppner et al., 1990; Cheesman et al., 2007; Gregory et al., 2011), we quantified the time devoted to ecology instruction by examining actual current course syllabi. In addition, we explored potential differences in ecological topic coverage among rural, suburban, and urban institutions, given that their proximity to natural habitats could offer fewer or more opportunities for ecological laboratory and field activities, thereby influencing instructional ecology coverage.

○ Methods

We categorized the 26 colleges and universities in our study as rural (6 institutions), suburban (10), and urban (10) according to context-sensitive definitions used by the Federal Highway Administration, U.S. Department of Transportation (Table 1). All institutions were located in Pennsylvania and metropolitan areas of Maryland and New York to eliminate variables that might arise from local issues and priorities in different regions of the United States. The biology department of each institution was contacted by e-mail in the fall of 2011, and syllabi were requested for the 2011–2012 semesters from introductory biology courses in each department to standardize the program classification. However, though all these courses were designed for biology majors, there was no exclusion of nonmajors from any course, so we considered all to have had a mixed audience. Of the schools contacted, 55% provided lecture and laboratory syllabi. A total of 103 syllabi were analyzed, because many of the courses used multiple syllabi and the courses ranged from one semester, lecture-only, to four-semester lecture and lab series.

The lecture and lab topics listed in each syllabus were sorted into one of eight categories for analysis: (1) *Cell/molecular/biochemistry*: study of morphology, function, and regulation of cells at the molecular level (as defined by the Society for Microbiology); (2) *Genetics*: study of genes at the molecular, cellular, organismal, population, or evolutionary level (Griffiths et al., 2000); (3) *Physiology*: study of functions of organ systems at multiple levels (as defined by the American Physiology Society, 2005); (4) *Developmental*: study of development, differentiation, and growth of multicellular organisms (as defined by the Society of Developmental Biology); (5) *Ecology*: study of relationships between organisms and their past environments (as defined by the Ecological Society of America); (6) *Evolution*: study of changes in gene frequency in a population and the descent of different species from a common ancestor (as defined by the Society for the Study of Evolution); (7) *Taxonomy*: naming, describing, and classifying organisms (Convention on Biodiversity, 2012); and (8) *Undefined*: all topics not belonging to the other categories, such as National Science Education Standards–related nature of science and scientific inquiry. In addition, the 20 essential topics surveyed by Gregory et al. (2011) were similarly grouped into these eight categories, and average importance (%; i.e., topic essentiality) and recommended topic coverage were calculated for each category (Figure 2).

Time devoted to each category was calculated as a percentage of coverage allocated to lectures and labs in course syllabi for each institution. In multi-semester series, time per topic was calculated as a percentage of the total number of lectures and labs in all the courses in the series. After determinations of normality (Kolmogorov-Smirnov test) and homoscedacity (Spearman rank correlation), a one-way analysis of variance was conducted to test for the effects of location on categorical coverage using SAS software (SAS Institute, Cary, North Carolina).

Table 1. Definitions of rural, suburban, and urban regions (Federal Highway Administration, U.S. Department of Transportation).

Region	Definition
Rural	Large expanses of undeveloped or agricultural land, dotted by small towns, villages, or any other small activity clusters
Suburban	Metropolitan areas that are lower density than cities and where land uses are often auto-oriented and segregated
Urban	Entirety of a major city: its downtown, commercial and industrial subdistricts, and neighborhoods

○ Results

Coverage of ecology. – Analysis of time devoted to ecology in introductory biology courses by each institution revealed a wide range of results (data not provided). Fifteen percent of the institutions devoted ≥30% of lab time to ecology. By contrast, 19% of the institutions identified no topic in the ecology category in their introductory courses. Of those institutions with no ecology coverage, 80% required an upper-level ecology course as part of their biology degree curriculum. The remaining 20% of these institutions did not include ecological topics in their introductory courses and offered ecology only as an elective, which was not a graduation requirement. Institutions also differed in the amount of time devoted to ecology in lectures compared to labs. Most institutions (71%) allocated more time to ecology in labs than in lectures (Figure 3).

Coverage of other topics in comparison with ecology. – Combined mean category coverage indicated that coverage fell into three groupings that were significantly different. Physiology (31 ± 5.3%) and cell/molecular/biochemistry (22 ± 2.52% lecture, 16 ± 2.23% lab) received significantly higher coverage in lectures and labs ($P = 0.02$) (Figure 3A) than any of the other topics. Coverage in evolution (14 ± 3.85% lecture, 11 ± 2.1% lab), taxonomy (12 ± 1.75% lecture and lab), and ecology (9 ± 2.8% lecture, 13 ± 1.5% lab) did not differ significantly from one another ($P = 0.65$), though they were covered significantly less than physiology and cell/molecular/biochemistry ($P = 0.02$). Genetics (6 ± 1.2% lecture, 8 ± 1.4% lab), "undefined" (3 ± 1% lecture, 7 ± 2.9% lab), and development (2 ± 0.8% lecture and lab) received significantly less covereage than all other topics ($P = 0.03$). Most topics received similar attention in both lectures and labs with the exception of the cell/molecular/

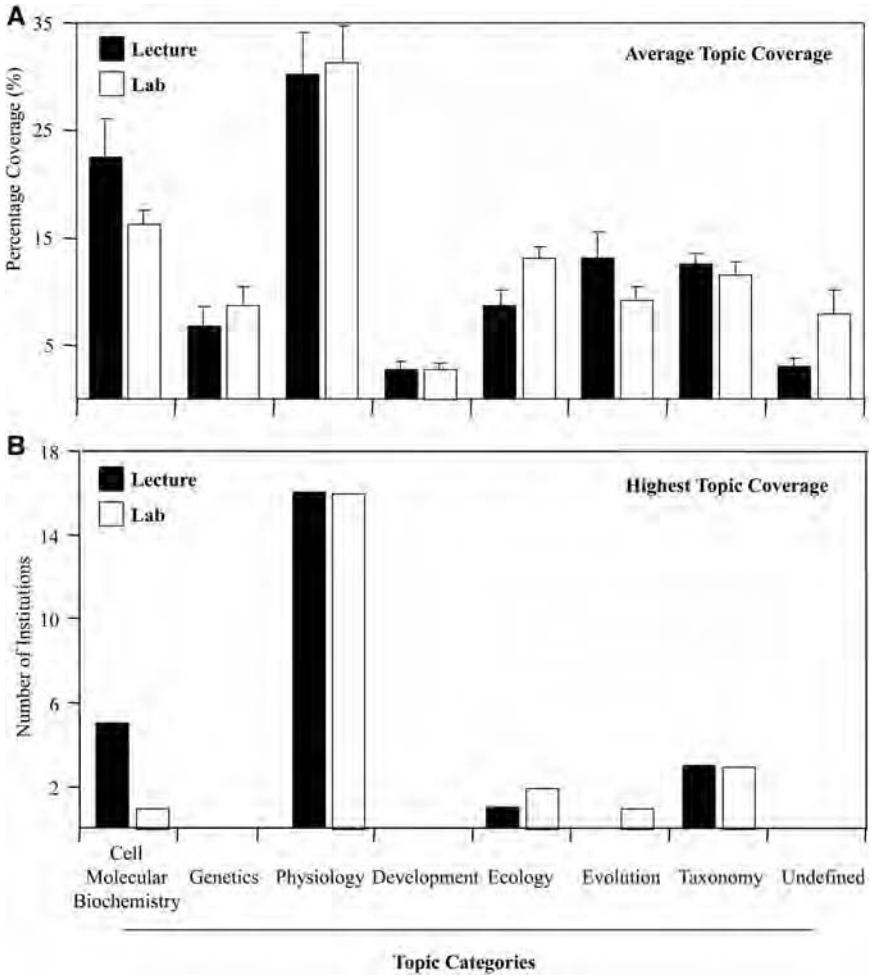

Figure 3. (A) Average coverage of eight topic categories in all institutions used in the present study. (B) Numbers of institutions providing the highest percentage of lecture or lab time to each of the eight topic categories. Institutions that gave equal time to more than one lecture topic (3.8%) or lab topic (7.7%) were not included in this graph.

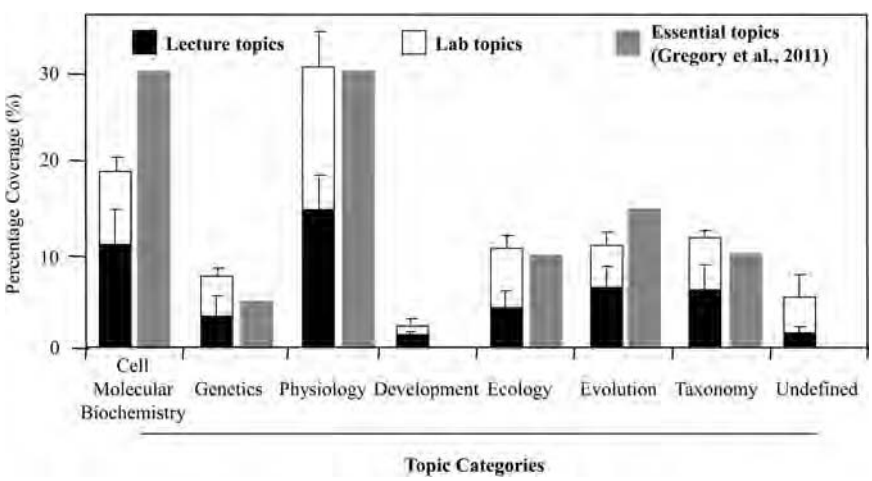

Figure 4. Average percentages of lecture and lab coverage in the present study compared with the category coverage by topic amounts considered essential by Gregory et al. (2011). Developmental and undefined categories were not included in the topics listed by those authors. Percentages of lecture and lab syllabi were halved prior to combining to maintain a topic total of 100%.

biochemistry and "undefined" categories. Development had the least coverage with no lecture or lab time at 42.3% and 53.8% of the institutions, respectively (not shown).

Only 23% of institutions covered all eight topic categories in lecture, and just 4% did so in lab. Most institutions showed a preference for physiology or cell/molecular/biochemistry topic categories, but some of the institutions placed more emphasis on other topics such as taxonomy, ecology, and evolution (in decreasing order; Figure 3B).

Comparison to essential topic categories. – Although introductory courses at individual institutions emphasized different topics, they included the essential topic categories recommended by NABT (Gregory et al., 2011; Figure 4), with physiology and ecology matching the recommended coverage ($P = 0.43$). In addition, schools dedicated significantly increased ($P = 0.035$) coverage to taxonomy, genetics, and "undefined": increases of 2%, 3%, and 5%, respectively, compared to the recommendations. Coverage of cell/molecular/biochemistry (19% actual, 30% recommended) and evolution (10% actual, 15% recommended) fell significantly below recommendations ($P < 0.01$).

Topic coverage by institutional location. – There was no significant difference in lab coverage of ecology between the three institutional locations ($P = 0.872$; Figure 5), though 67% of universities with the highest percentages of ecology lab coverage were urban. Institutional location also had no significant effect on lecture coverage in ecology ($P = 0.882$). In fact, 83% of institutions with no ecology lecture coverage were located in rural or suburban settings.

No significant difference in the presence of other categories was established (P values above 0.1), with a few exceptions (Figure 5). Rural coverage of evolution was significantly lower ($P = 0.036$) than the same coverage in suburban and urban location. In addition, cell/molecular/biochemistry was covered significantly more at rural locations ($P = 0.04$) than at suburban and urban locations.

○ Discussion

We compared ecology coverage to coverage of other topic categories, to the recommended NABT list of essential topics, and to institutional location. Our study comes at a time when the need for ecological literacy appears to lag behind vocalized expectations and concerns that literacy for understanding and addressing ecological concepts and issues needs to be increased (Jordan et al., 2009).

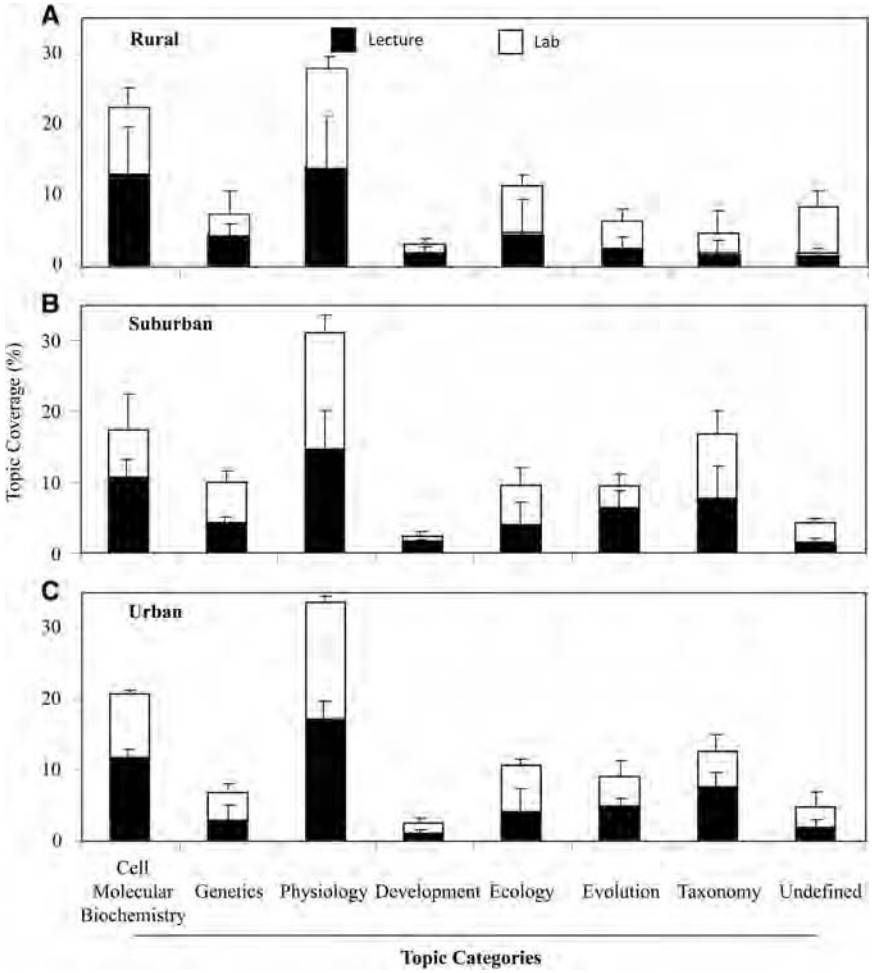

Figure 5. Comparisons of average lecture and lab time (%) devoted to the different categories at (A) rural, (B) suburban, and (C) urban institutions according to introductory biology course syllabi collected between 2011 and 2012.

Although individual institutions differed widely in their emphasis on ecology in introductory biology courses, with some devoting more time to ecology topics whereas others did not cover them at all, location did not appear to play a role in ecology coverage. Ecology lecture topics, in particular, were taught regardless of IHE location, whereas labs were taught utilizing ecologically authentic local field settings (i.e., natural areas, parks, streams, and woods) and employed lab-based activities, some including inquiry-based approaches (e.g., computer simulations of population dynamics and self-directed problem-solving exercises). These findings are noteworthy, given that urban settings are often viewed as less amenable to teaching ecology labs because of presumed (1) limited access to natural teaching environments and (2) non-use of inquiry and problem-based learning opportunities essential to ensuring that students learn and apply ecological content independently.

In addition, our results reveal that ecology coverage in introductory biology courses closely matches recommendations made by Cheesman et al. (2007) and Gregory et al. (2011), suggesting that ecology is currently valued as a topic category by the institutions and programs surveyed. However, the increased call for ecological literacy from the academic and scientific communities (Roberts et al., 2009; Levin, 2010) may not be matched by the typical ecological content coverage in introductory biology courses. Because ecological literacy remains woefully low in the general population (Jordan et al., 2009), the need for IHEs to provide focused guidance to increase ecological literacy is not reflected in actual ecology coverage in introductory biology courses at IHEs in the Mid-Atlantic region. Efforts to increase ecology coverage should therefore be made at IHEs to benefit all biology majors, especially for those intending to become secondary school teachers, given that ecologically literate teachers can best ensure that the general public will be more ecologically aware, literate, and able to participate in addressing local and global ecological issues.

The 29% coverage of physiology reflected Gregory et al.'s (2011) recommendation of 30% coverage between lecture and labs. Examination of the degree programs for institutions with the highest percentage of physiology found two possible explanations: (A) the institution/program may emphasisize physiological topics because of the need to train students in the allied and health sciences or (B) the institution/program may focus on physiology in introductory biology courses to provide basic coverage of the topic, given that either upper-level courses do not focus on physiology or no upper-division physiology courses are available. Cell/molecular/biochemistry topics, though covered below the recommendation by Gregory et al. (2011; 19% actual lecture and lab coverage, 30% recommended), were still covered to a greater extent than all remaining categories that showed coverages below 12%. This may partly reflect a lag by IHEs to address a growing emphasis on molecular biology skills needed by biology majors pursuing careers in the growing fields of biochemical engineering, molecular medicine, and pharmaceuticals. By contrast, college-level instruction for genetics and taxonomy was above the recommended coverage, which may reflect areas of instructor interest or bias, given that instructors were likely educated at a time when more importance was placed on these topics. Thus, with time, coverage of such topics may decrease to more closely match the recommendations by Gregory et al. (2011), while cell/molecular/biochemistry may increase to match them.

The present study is a first attempt, not to survey the needs of topic coverage suggested by administrators or NABT members, but to reflect the actual coverage of topic categories currently delivered in introductory courses at IHEs in different locations. Although we found that average ecology coverage across institutions was equal to that considered essential by Gregory et al. (2011), it raises the question of whether maintaining ecology coverage is enough to address the increased need for ecological literacy. Further, we found that differences in biology coverage at individual institutions suggest the importance of school selection in pursuit of a biology education. Given the lack of difference in ecology coverage across institutional locations, access to natural field settings in any location does not appear to influence how programs teach ecology. Instead, institutions find individualized means of teaching ecological topics, regardless of their location.

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