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Article

Characterization of Human Genetics Courses for Nonbiology Majors in U.S. Colleges and Universities

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We characterized college human genetics courses for nonscience majors (NSM) by 1) determining the number of U.S. institutions offering courses and the number of students taking them; and 2) surveying course instructors on course demographics, content, materials, and pedagogies. Between 2002 and 2004, an estimated 480 institutions of higher education (15.2%) offered a course: 8.4% of 1667 associate colleges, 16.1% of baccalaureate institutions, 25.3% of master's institutions, and 32.9% of doctoral institutions. This indicates a need to increase access to genetics education in 2-yr colleges. Based on instructor responses, approximately 32,000–37,000 students annually complete an NSM human genetics course out of approximately 1.9 million students earning a college degree each year (2.0%). Regarding course content, instructors consistently rated many concepts significantly higher in importance than the emphasis placed on those concepts in their courses. Although time could be a factor, instructors need guidance in the integration of the various concepts into their courses. Considering only 30.2% of the instructors were reportedly trained in genetics (another 25.4% in molecular and cellular biology) and the small fraction of students completing NSM human genetics courses, these results demonstrate the need for increasing the availability of these courses in undergraduate institutions of higher education, and particularly at 2-yr colleges.

INTRODUCTION

Significant advances in our knowledge of genetics were made during the twentieth century (Collins and McKusick, 2001), but in the most recent decades, genetic research has dramatically increased its impact throughout society. Hence, genetic issues are now playing a large role in health and public policy (Miller, 1998; Kolsto, 2001), and new knowledge in this field will continue to have significant implications for individuals and society (Lanie *et al*., 2004). Increasing the genetics knowledge of the general public, and specifically teachers, health professionals, and public leaders, will improve communication regarding genetic information and technologies, and it will help to ensure appropriate use of genetic applications (Haga, 2006). It is apparent that the educational system must begin producing a "genetically literate public that understands basic biological research, understands elements of the personal and health implications of genetics, and participates effectively in public policy issues involving genetic information" (National Research Council [NRC], 1994). Although this statement was made >12 yr ago, the need to make genetic literacy a common goal is even greater today.

In spite of the increased exposure to genetics, recent studies looking at the general public's genetics knowledge show relatively low understanding of genetics concepts (Petty *et al*., 2000; Human Genetics Commission, 2001; Lanie *et al*., 2004; Bates, 2005; Miller *et al*., 2006). Additionally, people are exposed to genetics informally through different types of media (Grinell, 1993; Nelkin and Lindee, 1995; Lanie *et al*., 2004), and the information presented is not always correct. Without knowledge of basic genetics, many find it hard to distinguish valid genetic information from misinformation (Jennings, 2004).

Studies specifically looking at the genetics knowledge of students in grade levels kindergarten to 12 (K–12) also show

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low levels of understanding. The 2000 National Assessment of Educational Progress conducted a study of approximately 49,000 U.S. students, and, on average, only ~30% of 12th graders could completely or partially answer genetics questions correctly (National Center for Education Statistics [NCES], 2000).

Educational opportunities in genetics for the general public most frequently come in the form of formal education. In 1995, the NRC published the National Science Education Standards (NSES) for K–12 that provide the basis for state science standards. Specifically, the NSES Science Content Standards indicate what students should learn within the clustered grade levels of K–4, 5–8, and 9–12, including genetics concepts (NRC, 1996). In grade levels K–4 and 5–8, the basic concepts of inheritance and reproduction are expected to be learned, whereas in grade levels 9–12 the molecular basis of heredity and biological evolution are covered. Thus, students graduating from high school should leave with a very basic but reasonably broad understanding of genetics, although there is no evidence available whether these standards produce genetically literate graduates.

Postsecondary education provides an additional opportunity for genetics education. There are >1.9 million individuals graduating with associate or bachelor degrees each year in the United States (NCES, 2004). Approximately 10% of graduates are in the life sciences and health fields (NCES, 2004), and perhaps they obtain an adequate amount of additional genetics education to result in genetic literacy. The other 90% of graduates may receive some genetics instruction through courses they take as part of general education requirements. A study of institutions indicated that >90% of the institutions surveyed have general education requirements allowing students to select from an approved list of courses organized by broad curricular groups, i.e., natural sciences, social sciences, and humanities/fine arts (Hurtado *et al*., 1991). Within the natural sciences, students may encounter courses exploring genetics topics; however, the proportion of students taking such courses is unknown. Additionally, the effectiveness of the courses in producing students who are genetically literate is unknown. If strides toward improving genetics education are to be made, assessment of the availability and quality of courses contributing to students' genetics knowledge is necessary. Such an assessment can only be accomplished after obtaining basic knowledge of such courses.

This study aims to address gaps in the current understanding of nonscience majors (NSM) human genetics courses at the undergraduate level through a national survey of their instructors and to make recommendations for improvement where appropriate. Specific objectives were to 1) estimate the number of NSM human genetics courses taught annually and the number of students taking them; 2) identify the institutions offering these courses according to their Carnegie classification; 3) summarize characteristics of the courses by determining instructor and course demographics, course content, instructional materials, and approaches used; and 4) compare these findings with previously published recommendations (Hott *et al*., 2002) on what content and concepts in genetics should be offered to undergraduate NSM.

MATERIALS AND METHODS

Step 1: Identifying NSM Human Genetics Courses

Data Sets. Three data sets supplied information regarding U.S. higher education institutions offering NSM human genetics courses:

1. The most recent comprehensive list of colleges and universities in the United States at the time of the study was obtained from the 2000 Carnegie Classification (McCormick, 2001). This list includes all 3153 degree-granting colleges and universities accredited by an agency recognized by the U.S. Secretary of Education, and it classifies those institutions by their degree-granting activities from 1995–1996 to 1997–1998.

2. Initial information on NSM human genetics textbooks was obtained from FacultyOnline (Monument Information Resource, 2002), which indicated three human genetics texts were being used for NSM courses: *Human Heredity: Principles and Issues* by Michael R. Cummings, *Human Genetics: Concepts and Applications* by Ricki Lewis, and *Basic Human Genetics* by Elaine Johansen Mange and Arthur P. Mange. The publishing houses of these three texts provided the most recently available adoption reports encompassing various editions and time frames (Table 1). There were 474 institutions in total that adopted at least one of the NSM human genetics texts between October 1998 and December 2002.

3. A list of instructors teaching a "genetics or heredity" course during the 2002–2003 academic year was purchased from MKTG Services, a commercial marketing firm that provides instructor information to publishers. MKTG Services collects this information primarily from class schedules obtained from the registrar's office of an institution, but it also uses school catalogs, directories, websites, and direct communication with academic departments (Hart, personal communication). This list indicated 1288 institutions had at least one instructor teaching a course in the broad area of genetics or heredity.

Step 2: Estimating the Number of Institutions Offering a Human Genetics Course for NSM

The above-mentioned data sets were collected during 2003, and they provided three different subsets of institutions: textbook adop-

Table 1. NSM human genetics texts adoption lists obtained from publishers

Text and author	Edition	Time frame
Human Heredity: Principles and Issues, Michael Cummings	5th	June 2000–Dec. 2001
	6th	Aug. 2002–Dec. 2002
Human Genetics: Concepts and Applications, Ricki Lewis	4th	June 2000–Dec. 2001
	5th	June 2002–Dec. 2002
Basic Human Genetics, Elaine and Arthur Mange	2nd	Oct. 1998–Dec. 2002

tion institutions, institutions having at least one instructor listed as teaching a genetics or heredity course (hereafter called the instructor list), and all others (hereafter referred to as the remaining institutions). Comparison of the databases revealed that 404 institutions were on both the textbook adoption list and the instructor list. The remaining 70 institutions adopting a textbook were not on the instructor list, indicating that MKTG Services' survey did not include all institutions with a genetics or heredity course. One reason for the discrepancy could be the differences in time periods of the two data sets; textbook adoption lists were from October 1998 to December 2002, and the MKTG Services' survey listed instructors for the 2002–2003 academic year.

The instructor list included a wide range of genetics and heredity instructors teaching courses at undergraduate and graduate levels. Thus, 884 of the institutions represented were not listed as adopters of one of the aforementioned texts for human genetics courses.

Website analysis was tested as a method of determining whether a human genetics course was offered at an institution on the instructor list. Institutions that had been identified as having a human genetics course because they had adopted one of the three human genetics texts and also were listed on the instructor list were used to validate a website survey methodology. A blind, random sample of 80 institutions was taken from the known list and mixed with a random sample of 80 institutions from the instructor list. The person who conducted the Web searches did not know to which of these two categories any of the institutions belonged. All of the Web searches were conducted during 2003. The institutional websites for all 160 institutions were searched for whether they taught a human genetics course. In determining this, the following components of institutional websites were examined: course listings, course descriptions, department listings, professor information, general search features, and bookstore listings. A course was identified specifically as a human genetics course when various permutations of "human genetics," "genetics and society," or "heredity and society" were in the course title, or the course used one of the three human genetics texts. An example of the course description of a "Genetics and Society" course from the University of Cincinnati (http://bioweb.ad.uc.edu/general.asp?subject = course) was as follows: "Principles of genetics as applied to humans. Includes DNA technology and genetic engineering, sexual reproduction and genetic variation, ethical, legal, and social issues of human genetics, issues of quantity and quality of the human gene pool, and practical applications of these topics to individuals and society. For non-science majors."

As a result of the website analysis, 72 of 80 (90%) institutions of the known group were identified as having a human genetics course. Course offerings at the remaining 10% of the institutions could not be verified due to websites not being updated or completely lacking course information. Our ability to verify such a high percentage of the institutions indicated that website analysis was a valid method of identifying human genetics courses, and it allowed us to estimate the number of institutions offering an NSM human genetics course from the instructor list and the remaining institutions.

Using information from the website analysis, we estimated that approximately 30% of the textbooks (described by the publishers as NSM human genetics textbooks) were being used in science major (SM) rather than NSM human genetics courses. Thus, it was necessary to distinguish NSM from SM courses in our data collection. In numerous instances, the course description stated the course was specifically for NSM (as seen in the course description given above). For courses where the audience was not indicated, prerequisite information was relied upon, because NSM courses generally do not have prerequisites.

We then estimated the number of institutions with NSM and SM human genetics courses in the instructor list and the remaining institutions. A random sample of 194 institutions from the instructor list (including the 80 institutions referred to above) and 100 institutions from the remaining institutions was investigated (Table 2). To produce a representative sample, the remaining institutions were stratified based upon the Carnegie classifications.

Within each population (textbook adoption institutions, instructor institutions, remaining institutions) and Carnegie classification of institutions searched, the percentage of institutions found to have an NSM human genetics course was estimated. The total number of courses throughout the country was estimated by multiplying the respective total number of institutions in each population subset (subdivided by Carnegie class) by the percentages of institutions found to have a course. However, each of the estimates needed to be corrected for the undercount found in the website analysis of the control group. This correction was based upon the Carnegie classification of each institution, because the undercount was different among the classes (Table 3). Summation of these results produced a final estimate of the number of NSM human genetics courses.

Step 3: Soliciting Information on NSM Human Genetics Courses

Creating the Instructors' Sample. Seventy-three of the 374 institutions searched (80 textbook list, 194 instructor list, and 100 remaining institutions list) were found to offer an NSM human genetics course. The websites of these institutions were searched to determine the course instructor and the instructor's e-mail address.

To obtain a larger sample of instructors to survey, a stratified random sample of 140 institutions remaining on the textbook adoption list was used. Of these institutions, 71 institutions were found to offer an NSM human genetics course, and they were added to the sample. In total, 144 instructors and their corresponding e-mail addresses were compiled: 122 from the textbook adoption list, 19 from the instructor list, and three from the remaining institutions. These instructors were invited to participate in the survey via e-mail, with an opportunity to respond if he or she was not the instructor and to name the current instructor. Nonrespondents were sent two follow-up e-mails. Of the 144 instructors, 79 responded to the e-mails, with 63 responding positively, yielding a response rate of 43.8%.

Creating the Survey and Pilot Testing. The survey instrument consisted of four main categories of questions: 1) course demographics; 2) course content; 3) instructional materials and teaching methods; and 4) instructor demographics. Course demographics included questions on the number of students completing the most recent NSM human genetics course taught by the survey respondent, the typical number of sections of the course taught each academic year, and the approximate number of students completing the course (including all sections) at their institution in an academic year. Because instructors were asked to choose the appropriate range of student numbers (e.g., <29, 30–59, etc.), averages were obtained using the midpoint value of each range and the percentage of instructors indicating each range.

In determining course content, survey questions were based upon the six central genetics content areas (The Nature of the Genetic Material, Transmission, Gene Expression, Gene Regulation, Evolution, and Genetics and Society) and 43 subconcepts defined by the American Society of Human Genetics (ASHG) Human Genetics Education Subcommittee (Hott *et al.*, 2002). Instructors were asked to indicate the percentage of the course dedicated to each content area and to rank the relative importance and emphasis of each

Table 2. Number of institutions in each population and the number searched

Population	Total no.	Total searched (%)
Textbook adoption institutions	474	80 (17)
Genetics instructor institutions	884	194 (22)
Remaining institutions	1795	100 (5.6)
Total	3153	374 (11.9)

Table 3. Number of institutions in the textbook listing searched and identified to have a human genetics course

Class[a]	Total	Searched	Identified (%)	% Undercount
Doctoral/research	115	21	20 (95.2)	4.8
Master's	156	27	26 (96.3)	3.7
Baccalaureate	90	16	13 (81.3)	18.7
Associate's	113	16	13 (81.3)	18.7
Subtotal	474	80	72 (90)	

[a] The eight Carnegie classifications were collapsed into four classifications such that doctoral/research includes doctoral/research universities—extensive and intensive; master's includes master's colleges and universities I and II; baccalaureate includes baccalaureate colleges—liberal arts and general; and baccalaureate/associate's colleges.

subconcept by using a five-point scale. Because of the large number of subconcepts within each content area, respondents were asked to complete the survey for only two content areas; thus, they were randomly divided as to which content areas they were asked to consider.

The questionnaire was modified after being reviewed by 13 individuals, including genetics professionals, genetics instructors, and survey research experts. The commercial Web design company SurveyFrog provided the expertise to develop and maintain the three online surveys (Supplemental Material A).

Data Analysis

The average percentage of class time spent on each content area was compared using analysis of variance (ANOVA) with a Tukey's post hoc test (Zar, 1999). The importance and emphasis ratings for each subconcept were condensed into two groups, 1–3 and 4–5, due to limited numbers. The importance and emphasis dichotomous ratings were then compared using McNemar's test of symmetry chi-square (Siegel and Castellan, 1988).

RESULTS

Estimating Number of Institutions Offering a Human Genetics Course for NSM

Institutions offering a human genetics course for NSM varied by Carnegie class and population subset (Tables 4 and 5). Of textbook institutions, 70.9% were estimated to have such a course. Not surprisingly, this is considerably higher than the estimated 10.3% of institutions on the instructor list and 2.9% of the remaining institutions (Table 4). Summation of the estimates for each Carnegie class and population subset resulted in a total estimate of 478 (15.2%) institutions in the United States offering an NSM human genetics course. When considering the Carnegie classifications, only 8.4% of 1667 associate colleges were estimated to offer such a course, in contrast to 32.9% of doctoral/research, 25.3% of master's, and 16.1% of baccalaureate institutions (Table 5).

Survey Results

Course Demographics. The instructors reported an average of 51 students completed the last human genetics course for NSM they taught. An average of 1.8 sections taught at each institution in an academic year meant an average of 92 students completed the course. This is consistent with in-

Table 4. Estimated number of institutions with an NSM human genetics course by class and population subset

Class[a]	Total	Searched	NSM courses	Corrected NSM courses (%)[b]	Estimated NSM courses (%)
Textbook institutions					
Doctoral/research	115	21	12	12.6 (59.9)	68.9
Master's	156	27	18	18.7 (69.1)	107.8
Baccalaureate	90	16	10	11.8 (74.2)	66.8
Associate's	113	16	11	13.1 (81.6)	92.2
Subtotal	474	80	51	56.2 (70.2)	335.7 (70.8)
Genetics instructor institutions					
Doctoral/research	124	39	5	5.2 (13.4)	16.7
Master's	333	77	9	9.3 (12.1)	40.4
Baccalaureate	306	59	3	3.6 (6.0)	18.5
Associate's	121	19	2	2.4 (12.5)	15.1
Subtotal	884	194	19	20.5 (10.6)	90.7 (10.3)
Remaining institutions					
Doctoral/research	21	9	0	0	0
Master's	124	19	1	1.0 (5.5)	6.8
Baccalaureate	217	19	1	1.2 (6.2)	13.6
Associate's	1433	53	1	1.2 (2.2)	32.1
Subtotal	1795	100	3	3.4 (3.4)	52.5 (2.9)
Total	3153	374			478.9 (15.2)

[a] The eight Carnegie classifications were collapsed into four classifications such that doctoral/research includes doctoral/research universities—extensive and intensive; master's includes master's colleges and universities I and II; baccalaureate includes baccalaureate colleges—liberal arts and general; and baccalaureate/associate's colleges.

[b] The values in this column have been adjusted according to the undercount factor to represent the estimated number of institutions having a course out of those searched.

Table 5. Estimated number of institutions offering an NSM human genetics course by Carnegie classification only

Class[a]	Total	Estimated NSM (%)
Doctoral/research	260	85.6 (32.9)
Master's	613	155.0 (25.3)
Baccalaureate	613	98.9 (16.1)
Associate's	1667	139.4 (8.4)
Total	3153	478.9 (15.2)

[a] The eight Carnegie classifications were collapsed into four classifications such that doctoral/research includes doctoral/research universities—extensive and intensive; master's includes master's colleges and universities I and II; baccalaureate includes baccalaureate colleges—liberal arts and general; and baccalaureate/associate's colleges.

structors independently reporting a total average of 89 students completing these courses in an academic year.

The survey also revealed approximately 75% of the NSM human genetics courses were taught every year, whereas 25% were taught on a variable basis. When considering 89 students on average completed the course per institution, and the frequency in which the courses are taught, approximately 32,000 students annually complete an NSM human genetics course in the United States. If those courses taught on a variable basis average being taught every other year, this would add an additional approximately 5000 students. Thus, these data suggest an estimated 32,000–37,000 students complete such a course each year.

Course Content. Half of the respondents reported spending <5% of class time on the basic processes of mitosis and meiosis, whereas 45% reported spending 5–10% of class time. A one-way ANOVA indicated significant differences existed between the time spent on the different content areas. The results of the ANOVA are summarized in Table 6. A Tukey's post hoc analysis provided additional insight on which content areas differed, and the results are indicated in Figure 1. Two of the six main content areas, Genetics and Society and Transmission, received the highest percentage of class time, 25.3 and 23.8, respectively (Figure 1), significantly more time than the other content areas ($p \leq 0.001$).

Instructors rated the importance of the subconcepts and relative emphasis placed on them during the course. On a scale of 1–5 (5 being the greatest), the overall average importance of the subconcepts was 4.1, whereas the average emphasis received in class was 3.7. Subconcepts of Gene Expression received the highest average importance rating (4.3) in contrast to Genetics and Society subconcepts, which received the lowest average importance rating (3.9). Although instructors consistently rated each subconcept higher in importance than the emphasis received in class (Figure 2), most importance and emphasis ratings did not differ statistically. The emphasis ratings for all subconcepts ranged from highs of 4.4 to lows of 2.5 (Figure 2), with Gene Expression receiving the highest average rating (4.0) and Evolution and Genetics and Society receiving the lowest average rating (3.5).

Instructional Materials and Teaching Approaches. The majority of respondents (95.2%) indicated they required students to use a specific textbook, with 55.9% using Lewis (2001, 2003) and 40.7% using Cummings (2000, 2003), whereas only two instructors reported using a different text. However, the sample of instructors was knowingly biased toward those institutions adopting Lewis, Cummings, or the Mange and Mange (1999) textbooks (122 of the original 144 sample, and 55 of the 63 respondents).

Instructors were asked to approximate how many hours they spent on various teaching methods (pedagogies) during the course. There was some discrepancy between the estimated average of 63 h the students were involved in the course and the total average of 72 h spent on the different pedagogies, perhaps explained by instructor approximations, overlapping pedagogies, lack of tallying total hours on the survey instrument, or a combination. Regardless, using time percentages based upon 72 h, and applying those to the 63-h base, the data provide a reasonable estimate of how class time was used (Table 7). An average of 27.5 h (43.8%) was spent lecturing or presenting material. Another 10.2 h (16.3%) consisted of "other" pedagogies, listed as various online activities (e.g., simulations and discussion boards), laboratory exercises, and student presentations. The least amount of time (3.0 h or 4.7%) was spent viewing videos.

All instructors reported using exams to assess student learning either always or frequently (Figure 3). More than 90% of institutions used at least three methods of assessing

Table 6. Summary of the ANOVA calculated for differences between the time spent on the six content areas

Source	df	MS	*F*
Groups	5	2017.28	27.16 ($p < 0.001$)
Error	360	74.28	

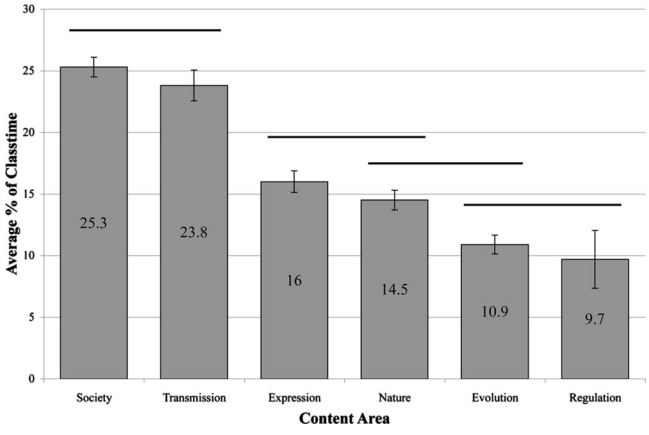

Figure 1. Average percentage of class time spent on the six genetics content areas in human genetics courses for NSM. The bars indicate there is no significant difference on the time spent on the content areas within the bars.

student learning (only two instructors reported using exams exclusively); besides exams, these included writing assignments, class discussion, group activities/projects, or problem sets (the latter two methods were used least frequently).

Instructor Demographics. Each instructor identified the discipline in which he or she was professionally trained. More than half reported being trained in genetics (30.2%) or molecular and cellular biology (25.4%) (Table 8); other disciplines were evenly distributed.

DISCUSSION

Estimated Number of Students Taking NSM Human Genetics Courses

We estimated that approximately 32,000–37,000 students, or around 2.0% (NCES, 2004) of those students earning a degree outside of the life sciences and heath fields, annually complete an NSM human genetics course. Yet, these are the graduates who will become community leaders, K–12 teachers, parents, and individuals increasingly in-

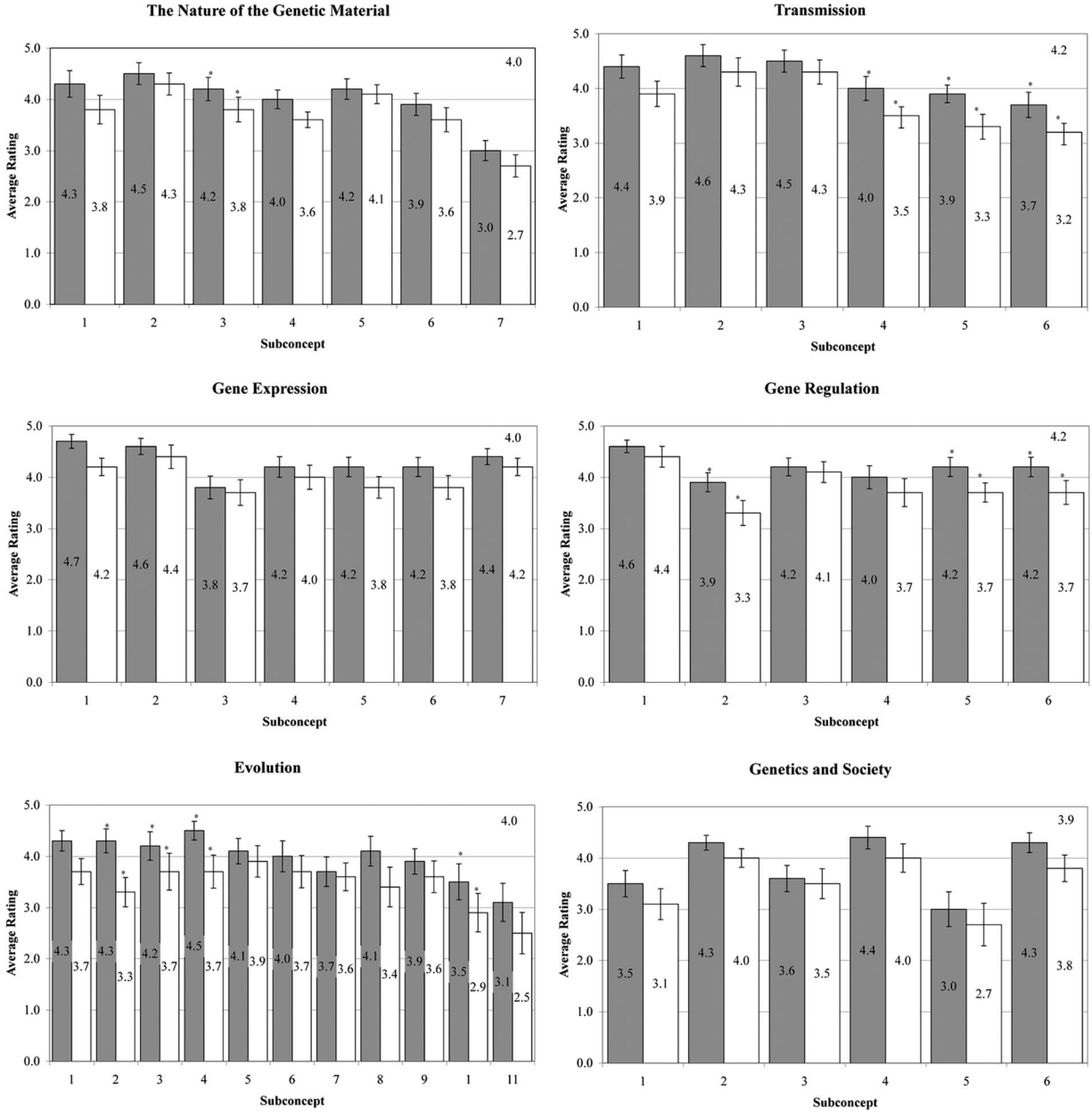

Figure 2. Average importance (gray) and emphasis (white) ratings for the 43 subconcepts within each of the content areas in NSM human genetics courses reported by instructors. The asterisks indicate a significant difference between importance and emphasis. Error bars indicate SE. Content area average importance is in the upper right of each graph.

Table 7. Percentage of hours of class time instructors reported spending on the different pedagogies

Pedagogy	% of Class time (h)
Lecturing/presentations	43.8
Other	16.3
Group work	12.0
Class discussion	8.8
Exams (quizzes, midterm, final, other tests)	7.4
Genetics in the news (present/discuss latest discoveries)	7.0
Videos	4.7

Table 8. Number of NSM human genetics instructors trained in the various scientific disciplines

Discipline	% Instructors
Genetics	30.2
Molecular/Cellular Biology	25.4
Botany	7.9
Microbiology	7.9
Ecology	6.3
Evolution	6.3
Other	6.3
Science Education	4.8
Zoology	4.8

terested in their own health care, all of whom will need sufficient genetic literacy to appropriately carry out these responsibilities.

To test this estimate (obtained through the instructor survey), we obtained independent data from two sources: McGraw-Hill publishing company and Monument Information Resource (MIR), a marketing firm that obtains data directly from bookstores and that sells these data to publishers. Both sources indicate an average of 45 books was sold per institution for NSM human genetics courses in 2003. This is substantially lower than our estimate of 89 studentsper institution, and it may be explained by several factors: used and online books sales, students not purchasing a book, and more than one bookstore servicing an institution. Used book sales compromise a large portion of the market, approximately 40% each year for human genetics courses (Shultz, personal communication). Furthermore, Shultz indicated student price sensitivity results in students not purchasing books, sharing books, and looking to alternative sources, also significantly influencing books sales. Thus, from these independent data, the estimate of 32,000–37,000 students participating in an NSM human genetics course each year seems to be a reasonable estimate.

Institutions Offering NSM Human Genetics Courses

Estimates for the number of institutions offering NSM human genetics courses varied significantly by Carnegie class (Table 5), with only 8.4% of associate degree institutions estimated to have such a course compared with 32.9% of doctoral institutions. Doctoral institutions are larger and have more faculty, thus allowing flexibility to teach more specialized courses such as NSM human genetics (Table 5). Also, faculty specialized in human genetics would more likely be located at a doctoral university and therefore be interested in teaching this topic. This same reasoning may apply to master's and baccalaureate institutions, but less so. In addition, only slightly more than half of instructors reported being trained in genetics (30.2%) or molecular and cellular biology (25.4%) (Table 8), and the latter training may only cover a subset of concepts relevant to NSM genetics.

One way to provide additional students an NSM human genetics course opportunity is to implement initiatives that prepare and encourage faculty at 2-yr colleges to teach such a course. The National Human Genome Research Institute in Bethesda, MD, has been providing leadership in this direction for several years on a small

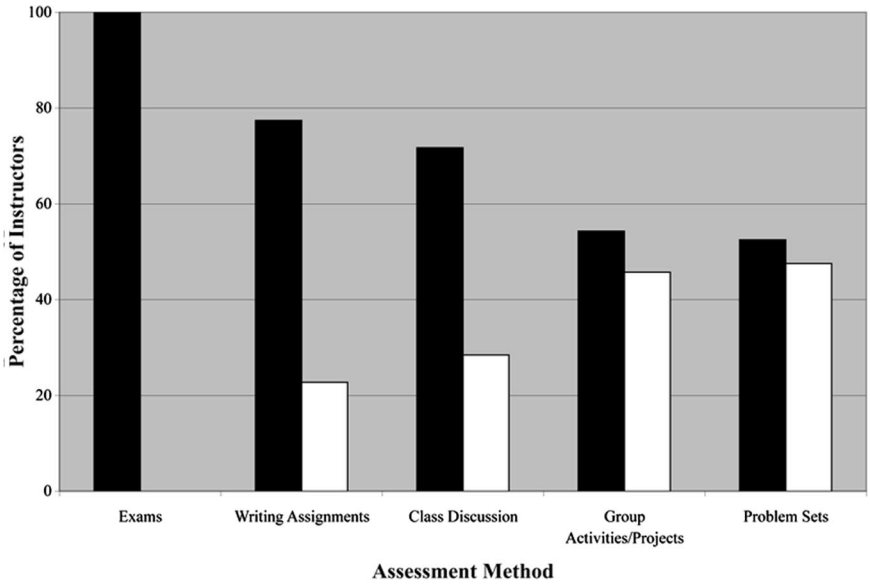

Figure 3. Reported frequency of methods of assessment used by instructors in NSM human genetics courses, always or frequently (black) and rarely or never (white).

scale, but there is need for increased involvement of professional geneticists in undergraduate genetics education to further this effort.

Content and Pedagogies Used in NSM Human Genetics Courses

Instructors reported that two content areas, Transmission and Genetics and Society, received a significantly greater percentage of class time, approximately 25% each (Figure 1). The considerable percentage of class time dedicated to Transmission genetics is not surprising, but this commitment to Genetics and Society is in contrast to the study by Hott *et al*., 2002 of genetics content in introductory biology courses, which found Genetics and Society to be one of the least discussed topics. Interestingly, however, the survey respondents gave Genetics and Society subconcepts the lowest average importance rating (3.9) (Figure 2). Previous studies (Haffie *et al*., 2000; Hott *et al*., 2002) indicated similar results in that instructors tend to cover the vast amount of fundamental material but fail to see the importance of integrating the concepts that are more relevant to students' lives.

Lecturing is the primary pedagogy instructors used, consuming approximately 45% of class time. However, instructors reported spending over a third of class time on active learning pedagogies (Table 7), including group work (12%), class discussion (9%), and others (e.g., laboratory exercises, student presentations, and online activities) (16%). This is positive, because research has consistently shown that students learn best when actively engaged (Hake, 1998; NRC, 2003). However, instructors reportedly spent approximately 7% of class time on "genetics in the news," a small percentage considering the vast amount of interesting genetic items present in the popular press directly relevant to students. More emphasis should be placed here, because it provides the opportunity for students to see how basic genetics concepts apply to their lives and how they are increasingly important to society on a daily basis.

Student Assessment

More than 90% of instructors reported they used at least three assessment methods to evaluate student learning (Figure 3). Educational research has found that assessment is best when it provides opportunity for feedback and revision and when it is aligned with learning objectives (NRC, 2000, 2003; McKeachie, 2002). Although details of how instructors used these multiple assessment methods is unknown (e.g., concept vs. fact based), their use of multiple assessments that incorporate critical thinking and interpersonal communication is in agreement with recommendations.

Study Limitations

Limitations include a response rate of only 43.8% from the study sample and that the sample was biased toward instructors using one of the cited textbooks. Additionally, the information assembled from this study helps us better understand what genetics concepts are being emphasized in undergraduate NSM human genetics courses, but it does not address what students are actually learning. The subconcepts authored by the ASHG Human Genetics Education Subcommittee (Hott *et al*., 2002) were developed as genetics concepts NSM undergraduates should understand, but how to assess that understanding has not been sufficiently addressed. It would be helpful to develop a standardized test that assesses students' learning of genetics concepts in a general biology or NSM human genetics course. Such a test would not only allow insight into student learning but also would contribute to assessment of the courses, pedagogies, and materials, and it would encourage improvement of undergraduate genetics education.

CONCLUSIONS

This study has estimated for the first time the number of human genetics courses offered in institutions of higher education by their Carnegie classifications, and the number of students who annually complete them, thereby raising awareness of the status of NSM human genetics courses in U.S. undergraduate institutions. It estimates that only approximately 2% of students who annually graduate outside of the life sciences have taken such a course, and it finds the need for such courses particularly acute in 2-yr colleges. Characterizing the content and pedagogy used in these courses through a survey of instructors also suggests the need for greater emphasis on applying genetic concepts and principles to the many issues directly relevant to the students, their families, and society generally.

These results document the need for increasing the availability of NSM human genetics courses in higher education, particularly at 2-yr institutions. One way to encourage this is for genetics professionals to become more involved in undergraduate education by offering opportunities that enhance instructor knowledge in genetics and teaching genetics. This might be through summer institutes for undergraduate faculty, similar to the National Human Genome Research Institute's Current Topics in Genomics Short Course, or through workshops such as those begun by the ASHG at its annual meeting in 2006. Enhancing the quality and quantity of undergraduate NSM human genetics courses will allow more students access to genetics education, thereby developing a society with the capacity to more effectively participate in genetic decisions affecting individuals and their families.

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