Different but equal? How non-majors and majors approach and learn genetics.

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Abstract

Are non-science majors really fundamentally different from science majors in their background knowledge, attitudes, and abilities? We compared students in two different genetics classes at CU, one for non-science majors, and the other for science majors taking genetics for their major or future careers. The teaching approach (clickers with peer discussion and weekly group activities) and the overall learning goals were the same in both classes. Students answered identical questions throughout the semester to measure content knowledge. These questions were given on a validated pre/post content assessment (Genetics Concept Assessment), un-graded quizzes after each group activity, and as part of each exam. To characterize how students learn genetics, we surveyed their attitudes, their time commitment to studying, and their study resources.

We found that the average pre-test score for majors (34.7%) was not significantly different from non-majors (30.3%), but by the end of the course, the majors significantly outperformed non-majors on the post-test (80.2% compared to 65.5%). In addition, performance on the shared quiz and exam questions showed that majors improved steadily, while non-majors made an impressive jump right after learning a topic (measured with quizzes), but then failed to improve further (non-majors avg. quiz score: 64.6%; avg. exam score: 67.8%; avg. post-test 65.5%). We also found that although non-majors and majors are surprisingly similar in many of the ways they approach learning genetics, there are some important significant differences. Majors study more, are more highly motivated, and more interested in the material. Our results indicate that majors and non-majors learn genetics differently, and to a different level, and that teaching non-majors requires finding new ways to engage and motivate them, especially outside of class.

Methods

Course design: similar for both courses

- Active learning approach: lecture interspersed with 3-5 in-class concept questions per class period (answered with clickers), with an emphasis on peer discussion of the questions.
- Weekly homework assignments (majors =11, non-majors = 8)
- Three exams, and a final.
- Weekly group problem solving sessions
  - Non-majors: one class period per week devoted to group problem solving activities rather than lecture
  - Majors: same problem solving activities were used in a separate group problem-solving session called a "co-seminar" in which students could voluntarily participate (for 1 credit, pass/fail). About half of the students in the majors class (71 out of 150) participated in the co-seminar; only these students have been compared to the non-majors

Assessments:

Content knowledge (shared, identical questions):
- Pre test (Genetics Concept Assessment; Smith et al., 2008)
- Quizzes given immediately after weekly group activities
- Exam questions on each of 3 exams
- Post test (Genetics Concept Assessment)

Attitude measures (shared, identical survey questions):
- Motivation, intimidation, interest, importance, difficulty
- Study habits
- Study time
- Attitude survey (Bio CLASS)

Shared learning goals for non-majors and majors genetics:

Learning Goal 1: Deduce information about genes, alleles, and gene functions from analysis of genetic crosses and patterns of inheritance.

Learning Goal 2: Describe the molecular anatomy of genes and genomes.

Learning Goal 3: Describe the mechanisms by which an organism's genome is passed on to the next generation.

Learning Goal 4: Compare different types of mutations and describe how each can affect genes and the corresponding mRNAs and proteins.

Learning Goal 5: Interpret results from molecular analyses to determine the inheritance patterns and identities of human genes that can mutate to cause disease.

Table 1. Demographics of the majors and non-majors courses

	Non-majors (n=66)	Majors (n=64)
Gender	62.7% female	60.6% female
Year	72.1% freshmen and sophomore	48.5% freshmen and sophomore
Major	6% Bio	62.5% Bio 98% science majors with future biology related career
Genetics background	25% never taken any genetics	7.2% never taken any genetics

Results

Overall, majors outperformed non-majors on every assessment except for the pretest.

Majors also continued to improve their scores on concepts as the semester progressed, while non-majors improved immediately after instruction (quizzes), but did not continue to improve further.

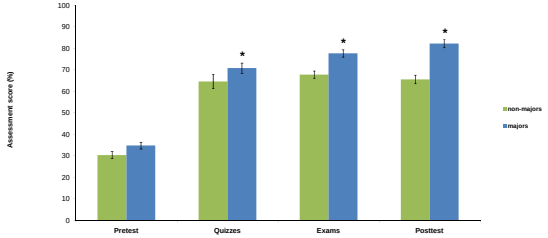

Figure 1. Progression of learning comparison between non-majors and majors.
Students were assessed at four different time points during the semester using identical questions. The average % correct for each assessment is shown for each group of students. Majors significantly outperformed non-majors on quizzes, exams, and on the posttest (*t-test, $p<0.05$).
There were 16 questions on the pre-post test (Genetics Concept Assessment-GCA), 21 shared quiz questions, and 23 shared exam questions.

Majors have a higher normalized learning gain (on the GCA) than non-majors

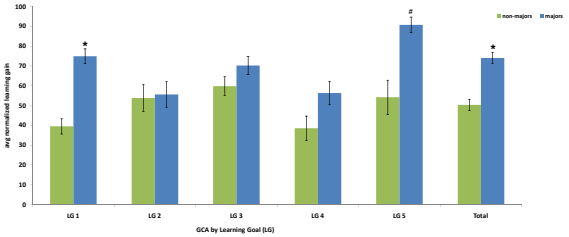

Figure 2. Average normalized learning gains for each shared learning goal (LG) from the pre-post assessment questions (Genetics Concept Assessment). Normalized learning gain is calculated using the formula (post-pre/100-pre). * t-test, $p<0.05$
#The GCA has only one question addressing LG 5. Therefore, the binomial distribution standard error of the mean is reported. The values are significantly different, $p<0.05$.

Quiz and Exam performance:
Majors outperformed non-majors on LG1 on quizzes and on nearly all LGs on exams

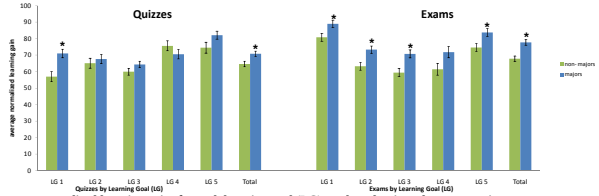

Figure 3. Average normalized learning gains for each learning goal (LG) on shared quiz and exam questions.
* t-test, $p<0.05$

Majors and non-majors have both similarities and differences in their attitudes

Similarities: Both groups felt overall positively about
- working with each other in small groups
- answering clicker questions in class
- discussing concepts with each other.

Differences: Non-majors are less interested, less motivated, and less intimidated

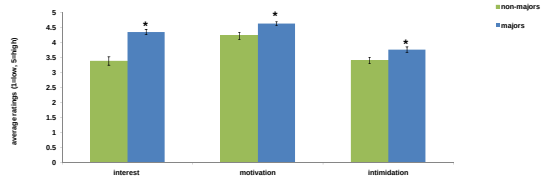

Figure 4. Student attitudes at the beginning of the course. Both majors and non-majors students were asked to rank on a scale from 1=low to 5=high how interested they were in the genetics course, how motivated they were to study for this course, and how intimidated they were by the course material. Majors were significantly more interested, more motivated, and more intimidated than non-majors. * $p<0.05$, Wilcoxon's rank-sum test

Non-majors study similarly to majors

Non-majors and majors both study clicker questions and activities in preparation for exams at a similar frequency, but majors are significantly more likely to study homework questions than non-majors.

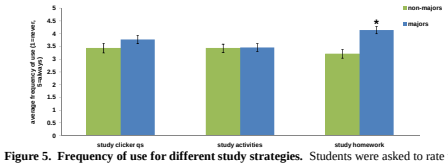

Figure 5. Frequency of use for different study strategies. Students were asked to rate the frequency (1=never, 5=always) with which they studied their homework, studied clicker questions, and studied the problem solving activities. Majors studied their homework significantly more than non-majors, but did not significantly differ in their other study strategies. *$p<0.001$, Wilcoxon's rank-sum test

Non-majors do not study as much as majors per week or in preparation for exams

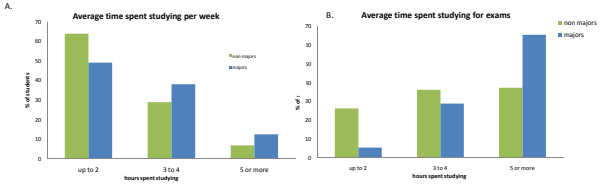

Figure 6. Study time comparison between non-majors and majors.
A. Average time spent studying per week, outside of time spent working on problem sets (self report, at end of each problem set). Majors spent significantly more time studying for the class, $p<0.001$, Wilcoxon's rank-sum test
B. Average time spent studying for each exam, anonymous self report in the class period after each exam (3 exams, each class). Majors spent significantly more time studying for exams, $p<0.001$, Wilcoxon's rank-sum test

Ranking of genetics compared to other courses

- Students were asked to rate their genetics course compared to the other courses they were currently taking with regards to studying, difficulty, importance to career and interest level.
- Values closer to 1 indicate that students spent more time studying for genetics than other courses and felt genetics was more important for their future career, more interesting, and more difficult than other courses.

Table 2. Average ranking for genetics for time studying, difficulty, importance to future career and interest level. SEM is in parentheses.

	Time Studying	Difficulty	Importance to Career	Interest Level
Majors	0.68 (0.03)	0.70 (0.04)	0.74 (0.04)*	0.80 (0.03)*
Non-majors	0.66 (0.03)	0.73 (0.04)	0.37 (0.04)*	0.62 (0.04) *

•Both majors and non-majors gave their genetics course a high (and similar) rank for time they spent studying and the difficulty of the course. Majors ranked their genetics course significantly higher (* t-test, $p<0.05$) in terms of importance to their future career and interest level.

Attitudes towards science as measured by the BioCLASS

This survey measures students attitudes towards science with 36 questions that fall into the 7 categories shown below. Student responses are compared to experts (Ph.D. biologists) and reported as percent agreement.

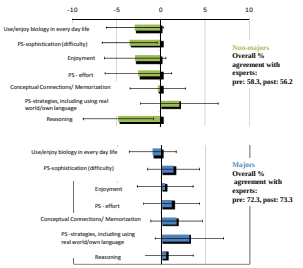

Figure 7. Non-majors are less sophisticated (less expert) in their views than majors.

Neither group of students shows a significant negative shift in their attitudes (a common problem in intro physics and chemistry courses) at the culmination of the course.

Conclusions

In comparing non-majors to majors in similar genetics classes, non-majors:
- Have positive learning gains, but not as high as majors
- Stall in their understanding (measured by performance) as the course progresses
- Show less interest, motivation, and intimidation when compared to the majors
- Study less

To improve the performance of non-majors we will:
- Motivate them to study more outside of class
- Emphasize effective studying
- Better stimulate their interest in the subject
- Emphasize topics that they find relevant