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 concept assessment (Genetics Concept Assessment, GCA), ungraded 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 habits. We found that the average pre-test score for majors (54.7%) was not significantly different from non-majors (53.7%), but by the end of the course, the majors significantly outperformed non-majors on the post-test (83.2% compared to 65.5%). In addition, performance on the shared quiz and exam questions showed that majors improved immediately, 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 score: 80.2%). We also observed that although non-majors and majors use strategies 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.

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.

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.

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

Methods

Course design: similar for both courses
- Active learning approach: lecture interspersed with 3-5 in-class concept questions per class period associated 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
- 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 all the students in the majors (71 out of 150) participated in the co-seminar; only these students have been compared to the non-majors

Assessment:
- Content knowledge (shared, identical questions):
  - Pre-test (Genetics Concept Assessment, GCA); 21 shared, 23 compared to the non-majors
  - Post-test (Genetics Concept Assessment, GCA)
- Attitude measures (shared, identical survey questions):
  - Motivation, interest, importance, difficulty
  - Study habits
  - Study time
  - Attitude survey (Bio CLASS)

Shared learning goals for non-majors and majors:
- Learning Goal 1: Deduce information about genes, alleles, and gene function 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 genetics 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 cause autosomal disease.

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

<table>
<thead>
<tr>
<th>Gender</th>
<th>Non-majors (460)</th>
<th>Majors (600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50%</td>
<td>52%</td>
</tr>
<tr>
<td>Female</td>
<td>50%</td>
<td>48%</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/13</td>
<td>10%</td>
<td>9%</td>
</tr>
<tr>
<td>13/14</td>
<td>85%</td>
<td>90%</td>
</tr>
<tr>
<td>Freshmen and sophomore</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figures

Figure 1. Progression of learning comparison between non-majors and majors.

Figure 2. Average normalized learning gains for each shared learning goal (LG) from the pre-post test assessment (Genetics Concept Assessment). Normalized learning gain is calculated using the formula (post-pre/100-pre). * = p<0.05.

Figure 3. Average normalized learning gains for each LG on quizzes and on nearly all LGs on exams.

Figure 4. Student attitudes at the beginning of the course.

Figure 5. Non-majors are less sophisticated (less expert) in their views than majors.

Figure 6. Study time comparison between non-majors and majors.

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

Conclusions

In comparing non-majors to majors in similar genetics classes, non-majors:
- Have lower learning gains, but not as low as non-majors
- Show less interest and motivation, and intimidation when compared to the majors

To improve the performance of non-majors we will:
- Motivate them to study more outside of class
- Emphasize effective studying
- Emphasize the importance of their study habits
- Emphasize that their final review

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

<table>
<thead>
<tr>
<th>Time Studying</th>
<th>Difficulty</th>
<th>Importance to Career</th>
<th>Interest Level</th>
</tr>
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<tbody>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Majors</td>
<td>64.8 (9.8)</td>
<td>79.0 (12.0)</td>
<td>75.6 (15.0)</td>
</tr>
<tr>
<td>Non-majors</td>
<td>59.3 (17.1)</td>
<td>66.6 (15.0)</td>
<td>58.9 (11.9)</td>
</tr>
</tbody>
</table>

* Both majors and non-majors give 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 = 5.04, p<0.05) in terms of importance to their future career and interest level.