Chicks and Their Genes: A Collaborative Method for Teaching Upper-division Laboratory Courses at a Small Women's College

CEDAR CREST COLLEGE

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Abstract

Upper-division college biology courses are often taught separately, with information compartmentalized under course titles such as "Animal Behavior" or "Genetics." The consequence of dividing the biological sciences this way ultimately produces students who may have gained depth in two or more distinct sub-disciplines, but who are unable to connect related concepts – the "bigger picture" so often missed by the typical student. To purposefully illustrate and facilitate student understanding of the connections between sub-disciplines, a crossover lab was designed between the Developmental Biology (BIO 332) and Molecular Genetics II (BIO 336) courses at Cedar Crest College during the Spring 2010 semester. While this lab served as only one of several exercises covered in each laboratory course, it allowed students of both populations to experience a segment of a class in which they were not currently enrolled and to meet the project goal of forging a connection between two biology sub-disciplines. Implementation of the crossover lab began with the developmental biology students qualitatively examining the effects of teratogens on chick embryo development. The project was continued in the molecular biology lab where students conducted a microarray-based experiment comparing gene expression in control versus treated embryos; arrays were obtained through the HHMI-funded GCAT program. The goal was for students from both labs to utilize the data generated by the microarrays to draw quantitative conclusions regarding the effects of the teratogens. Students from both classes collaboratively created research posters detailing the entire experiment. Finally, students were required to present their results to the entire class as well as at a local college conference, which meant they needed to understand the entire project, even the parts that they were not personally responsible for conducting. The project was assessed through an evaluation of the students' poster presentations and the use of pre- and post-tests containing both developmental and molecular questions. The results of the assessments, lessons learned by the faculty involved, and implications for future course collaborations will be presented. Sample data from the project and examples of the student posters will also be available for review.

Cedar Crest College and its Students

The College, Departments, and Majors:

Cedar Crest College is a liberal arts college located on the outskirts of Allentown, PA. The total enrollment of the college is approximately 1400, but a good proportion of these individuals are nontraditional "Life Long Learning" students, taking courses as part of an evening college. The day school is a women's college composed primarily of traditional-aged female students. There are two science departments at Cedar Crest, The Department of Biological Sciences and The Department of Chemical and Physical Sciences. The former houses five majors: Biology, Biodiversity and Conservation Biology, Genetic Engineering, Neuroscience, and Nuclear Medicine (the only co-ed major), while the latter houses Biochemistry, Chemistry, and General Science.

Project Goals:

All Biological Sciences majors complete a common core set of required courses, followed by a subset of major-specific courses and elective courses. Our goal was to involve students from two upper-level laboratory courses in a joint experimental project to enhance learning of concepts traditionally considered part of each course, as well as to provide a new opportunity to learn concepts taught in the other course.

Student Participants:

Students in two upper-level courses participated in this project:

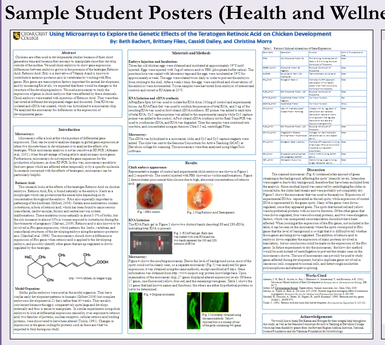
- Developmental Biology (BIO 332): an elective course for Biology, Genetic Engineering, and Neuroscience majors offered in alternate Spring semesters, taught by A. Ettinger
- Molecular Genetics II (BIO 336): a required course for Genetic Engineering majors and an elective course for Biology and Biochemistry majors offered every Spring, taught by K. Joy Karnas
- This project was approved by Cedar Crest College's Institutional Review Board for work with human subjects. Students consented to have their test scores and comments used for research purposes, and could choose not to participate in the assessment process without penalty.

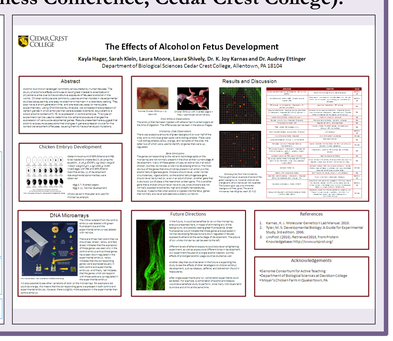
This year's enrollment for both courses was somewhat less than in previous years; however, the composition of majors within each course was fairly typical. There were a few overlapping students between the two courses (either taking both lectures or having previously taken one of the lecture/lab courses), but no students were concurrently enrolled in both laboratories. For our purposes, students were classified based on their lab enrollment in the current semester; a small group (N=3) of students enrolled only in the Development lecture served as a control group.

The table below summarizes the distribution of majors in the course:

Course Number	Total Enrollment	Biology Majors	Genetic Eng. Majors	Neuroscience Majors
BIO 332 Lecture	8	3	2	3
BIO 332 Lab	4	3	1	0
BIO 336 Lecture	13	1	12	0
BIO 336 Lab	12	0	12	0

Sample Student Posters (Health and Wellness Conference, Cedar Crest College):


Using Microarrays to Explore the Genetic Effects of the Teratogen Retinoic Acid on Chicken Development
By: Beth Bachert, Brittany Files, Cassidi Dailey, and Christina Morra


The Effects of Alcohol on Fetus Development
Kayla Hager, Sarah Klein, Laura Moore, Laura Silvely, Dr. K. Joy Karnas and Dr. Audrey Ettinger
Department of Biological Sciences Cedar Crest College, Allentown, PA 18104

Molecular Student Quotes:

"I think the microarray…was the most interesting to me because it had direct real life relevance, and it is a cool technique to know"

"DNA microarrays [were my favorite molecular lab experience this year] because it was an interesting technique to learn and is most likely a technique I'll have to use in grad school (for Cancer Bio☺) and other future research."

"My most favorite experience was seeing the finished microarray. It is not commonly done in undergraduate study and was a big undertaking, so getting the results back was awesome."

"Although it was unsuccessful the way we wanted it to work, I enjoyed the microarray project. It was like real research and let me learn about microarrays"

"I disliked the microarray analysis using MAGIC Tool since it was extremely frustrating."

"My least favorite experience was gridding and re-gridding the microarray using the MAGIC Tool software. It was unnecessarily complicated and sensitive, and the program had a lot of quirks."

"Microarrays-working with MAGIC Tool to analyze them was a pain in the butt, otherwise I liked the idea and what we learned from them."

"While no fault of the instructors it would have been nice if Magic Tool was easier to use."

"All of the simulations were very helpful in understanding the big picture of what we were doing. However, it was very frustrating that it did not work the way we wanted it to."

Development Student Quotes:

"Thought it was a great learning experience for all of us, including the professors."

"The interaction between the two labs enabled both classes to gain knowledge about developmental processes and molecular techniques, instead of only focusing on one aspect."

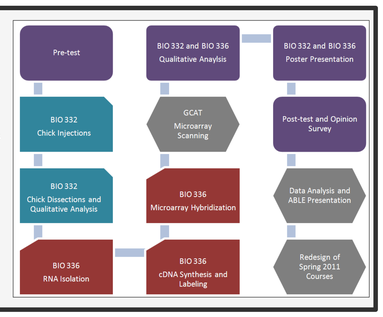
"Participating in this experiment was very enlightening on an interesting experimental technique that helped increase my understanding of the development of multicellularorganisms and outside factors that effect its development."

"This lab taught me that perseverance is important in science because if we gave up when something doesn't work, we wouldn't learn anything new."

Figure 1: The Approach

The flowchart to the right illustrates the overall plan for the project, beginning and ending with a written test that assessed student understanding of Developmental Biology and Molecular Biology of Microarrays. Purple boxes represent tasks performed by all students involved in the project, while blue and red represent Development and Molecular Biology students respectively. Grey boxes represent tasks not performed by lab students.

The chicken microarrays were obtained from the Genome Consortium for Active Teaching (GCAT), an ongoing project sponsored by the Howard Hughes Medical Institute to "bring functional genomic methods into undergraduate curricula." GCAT provided low-cost microarrays, slide scanning, and analysis software(www.bio.davidson.edu/GCAT).



Student Group	# of Students Surveyed	Pre-Test Mean Score	Post-Test Mean Score	Net Change in Score
Molecular Lecture/Lab	Pre: 12 Post: 10	57%	83%	+26%
Development Lecture/Lab	4	61%	82%	+21%
Both Labs Combined	Pre: 16 Post: 14	58%	83%	+25%
Development Lecture Only	3	45%	63%	+18%

Figure 2a: The Comprehensive Data

The table above shows the mean scores of all of the students who took the pre and/or post-test. The students were divided into three categories: students enrolled in 1) BIO 336 lab and lecture, 2) BIO 332 lab and lecture, and 3) BIO 332 lecture only. The third row (Both Labs Combined) represents pooled data from both lab courses - all of the students who participated in the entire project. Note that two BIO 336 students did not complete the post-survey; one of these students had withdrawn from the course prior to the completion of the project. All students showed a large improvement in test scores; however, students who participated in the project showed larger gains than those enrolled in the Development lecture only. This control group is a small sample (N=3) and began with a lower mean score, due to one individual's very low score on each exam (see figure 2b).

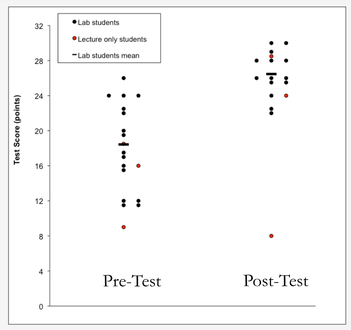


Figure 2b: The Comprehensive Data

The scatter plot above shows the scores for all students enrolled in both labs (black circles) and students enrolled in the Development lab only (red circles). The points on the left and right indicate scores for the pre- and post-test, respectively. Note that one individual Development student under-performed on each of the tests.

Content Learning Within and Across Courses

The pre/post-test multiple choice questions can be subdivided into questions dealing with developmental biology (Figure 3) and questions concerning the molecular biology of microarrays (Figure 4). For each question, data is given as the percentage of students who correctly answered the question (# of correct responses ÷ number of respondents x 100%). Total % correct takes into account the total number of questions asked (# of correct responses ÷ (number of respondents x number of questions) x 100%).

Student Group	# of Students Surveyed	Q1 % Correct Answers		Q2 % Correct Answers		Q3 % Correct Answers		Q4 % Correct Answers		Q5 % Correct Answers		Total % Correct Answers	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Molecular Lecture/Lab	12	10	92%	90%	58%	70%	25%	50%	25%	70%	50%	80%	50%	72%
Development Lecture/Lab	4	4	75%	100%	100%	100%	75%	25%	25%	75%	50%	100%	65%	78%
Both Labs Combined	16	14	88%	93%	69%	79%	38%	43%	25%	71%	50%	86%	54%	74%
Development Lecture Only	3	3	33%	67%	67%	67%	67%	33%	100%	100%	100%	100%	73%	54%

Figure 3: Assessment of Developmental Biology concept learning. Students enrolled in the lab associated with either course improved their understanding of Developmental Biology concepts. Students in Molecular Genetics scored only 4% lower than their Development counterparts (72% vs. 78%). The students not enrolled in lab showed a decrease in concept learning, likely due to the margin of error on scores from a small group.

Student Group	# of Students Surveyed	Q1 % Correct Answers		Q2 % Correct Answers		Q3 % Correct Answers		Q4 % Correct Answers		Q5 % Correct Answers		Q6 % Correct Answers		Q7 % Correct Answers		Q8 % Correct Answers		Total % Correct Answers	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Molecular Lecture/Lab	12	10	83%	90%	25%	90%	92%	100%	33%	60%	25%	50%	67%	90%	50%	100%	33%	100%	44%	85%
Development Lecture/Lab	4	4	100%	100%	50%	25%	25%	75%	75%	100%	0%	50%	75%	100%	75%	100%	25%	75%	53%	78%
Both Labs Combined	16	14	88%	93%	31%	71%	75%	93%	44%	71%	19%	50%	69%	93%	56%	100%	31%	93%	52%	83%
Development Lecture Only	3	3	67%	33%	0%	0%	33%	67%	33%	67%	0%	67%	33%	67%	0%	67%	0%	67%	21%	54%

Figure 4: Assessment of Molecular Biology of Microarrays concept learning. Students enrolled in the lab associated with either course improved their conceptual understanding of the Molecular Biology of Microarrays. The small group of students enrolled only in Development lecture also improved their content scores, but to a lesser degree (final score of students without lab: 54%, Development students with lab: 78%).

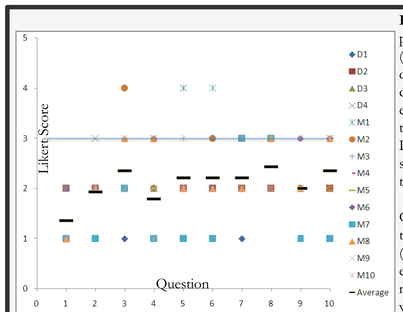


Figure 5: Satisfaction Survey. At the completion of the project, students were given a Likert scale satisfaction survey (1: strongly agree, 2: agree, 3: neutral, 4: disagree, 5: strongly disagree) to determine which portion(s) of the project (e.g. collaborating, microarray simulations, poster presentation, etc.) enhanced their learning experience. The scatter plot to the left shows the individual responses of the four Development students (D1-D4) and ten Molecular Genetics students (M1-M10) to the ten questions that were asked and the overall mean response.

On average, students felt that all of the activities enhanced their learning, as all response averages fell well below neutral (blue line). Students felt most strongly that the microarrays enhanced their understanding of microarrays (Q1) and molecular biology (Q2). They also felt that collaborating with students in their own course enhanced their learning (Q4). They did not feel as strongly about collaborating with students in the other course (Q5).

The Chicks: BIO 332 in Past Years

The lecture for Developmental Biology includes both an historical approach to the field and modern, molecular based approaches. Past offerings of the laboratory have been inquiry-based, beginning with several simple model organisms (Dictystelium, Planaria, Sea Urchins) to allow students to design and execute their own experiments. The final weeks of the semester involved an experiment exploring the effects of presumed teratogens on developing chick embryos. Students selected their chemical of interest (e.g. thalidomide, retinoic acid, ethanol, caffeine, etc.) and injected it into fertilized chicken eggs, with appropriate controls. Following a period of incubation (1-2 weeks), students dissected the embryos and macroscopically examined the chick anatomy. Students were able to do a thorough qualitative analysis of the embryos and apply information that they had learned in the lecture portion of the class to this project.

The Chicks: BIO 332 Spring 2010 Changes

This year, the chicken experiment was carried out early in the semester to facilitate the collaboration across courses, and thus occurred before chicken development was covered in lecture. One pair of students was asked to use retinoic acid as a teratogen based on the extensive literature showing effects of retinoic acid on developing embryos through its action on Hox genes. The second pair of students chose ethanol from a short list of options of less-studied teratogens. Chemical concentrations for injections were based on literature searches by the students; control eggs were injected with solvent only. Embryos were injected at day 0 or day 7, and allowed to develop for one week. After qualitatively examining the embryos, tissue samples from experimental and control embryos were collected and stored in RNAlater, an RNA preservative.

To enhance learning, students participated in both an online computer simulation and hands-on lab simulation to demonstrate how microarrays are created and interpreted. In addition, the lecture component of the course included the reading and discussion of one primary literature paper (of four total) that used microarrays to address questions in developmental biology. At the close of the project, students spent several lab sessions analyzing the data generated from the arrays and worked in collaboration with the Molecular Genetics students to produce research posters for the College's Health and Wellness Conference. Since each pair of Development students had produced samples for three sets of microarray analysis, these students contributed to each of the three resulting posters.

The Chicks: Challenges

The microarray project took more time than anticipated, with additional lab time needed for chick injection, tissue isolation, and data analysis. Therefore, the inquiry-based aspects of the course were reduced compared to previous years, and students spent less time on self-designed experiments using simple model organisms. This timing issue can be be addressed in future years by shifting the inquiry-based projects later in the course to allow for both types of lab experiences. In addition, because the Development lab was so much smaller than the Molecular Genetics lab, each Development student worked on several final poster presentations; working on a single poster might help to increase student satisfaction with collaborating across the courses.

The Genes: BIO 336 in Past Years

One of projects annually conducted by BIO 336 students involves the selection of an organism and a search of the NCBI database for a gene previously cloned and sequenced from that organism. Students isolate RNA, create cDNA, and then attempt to clone their gene of interest using primers that they designed specifically for that gene. After successfully amplifying the gene by PCR, students ligate their product into an expression plasmid, and then have their choice of various endpoints: restriction map it using enzymes they've identified as useful, sequence it, express the gene and analyze it using SDS-PAGE, etc.. Not all students generally make it to the end of this lab, but those who have difficulties early on usually learn valuable lessons on how to trouble-shoot experiments and how to design alternative plans for a project (e.g. using genomic DNA as an alternative to RNA and how this changes the final product with the inclusion of introns).

The Genes: BIO 336 Spring 2010 Changes

Students began their gene cloning as in previous years to gain experience in working with RNA prior to the start of the microarray experiment. After tissue samples were made available by the Development students, the Molecular Genetics students isolated RNA from these samples, copied this RNA to cDNA, differentially labeled control and experimental pools, and hybridized the labeled cDNA to slides that had previously been spotted with more than 21,000 chicken genes. After these slides had been scanned by GCAT, students had the opportunity to analyze the data and work in collaboration with the Development students to produce research posters for the College's Health and Wellness Conference. In addition, students participated in the same online computer simulation and hands-on lab simulation as the Development students to learn about how microarrays are created and read.

The Genes: Challenges

Some challenges arose when the standard microarray protocol was carried out for six slides at a time by twelve individuals, and these issues will be straightforward to address in future experiments. In addition, this project took over the entire semester, and little time was focused on other exercises typically carried out in this course. Streamlining of the protocols and requiring each student to prepare a set of RNA samples would help eliminate the need for having to repeat procedures when not enough RNA was obtained initially. The bioinformatics software recommended by GCAT (Magic Tool) had more of a learning curve than initially anticipated and also had a few quirks that frustrated the students, so the instructors will investigate other microarray analysis software options. Finally, students voiced difficulty in developing posters with students from the other class; communication seemed to be a challenge for them.

Future Collaborations

The collaboration across courses achieved its primary goals of enhancing learning of material within each course and allowing an opportunity to learn material from the other course. Therefore, we intend to continue using microarray experiments across courses to enhance student learning.

In the spring of 2011, A. Ettinger will offer a course on Diseases of the Nervous System (BIO 348). In the past, the lab for this course has used a variety of experimental approaches typically used to study these diseases. For a collaborative project, students will prepare primary cultures of chick neurons. The neurons will be induced to carry out apoptosis using glutamate treatment as a model for stroke and other neurodegenerative diseases. Some cultures will be treated with *Gingko biloba* to test whether this herbal dietary supplement can contribute to neural survival. Once again, the BIO 336 students will have the opportunity to utilize molecular approaches as they use the cells collected by the BIO 348 students in a microarray experiment. The intention is again to have the students collaborate on the data analysis and present their findings at the Cedar Crest College Health and Wellness Conference at the end of the semester.

Once again, pre- and post-test data will be collected to asses the impact that this collaborative laboratory has on student learning within and across the curriculum. This time, to better assess individual student learning, students will be identified by a coding system so that individuals can be tracked from beginning to end.