

REVITALIZING GENETICS COURSES THROUGH COLLABORATIVE RESEARCH AND SHARING BEST PRACTICES

FINAL REPORT OF ACS MELLON FOUNDATION FUNDED ACTIVITIES

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PAMELA HANSON, BIRMINGHAM-SOUTHERN COLLEGE (phanson@bsc.edu; 205-226-4881)
AND MARY MILLER, RHODES COLLEGE (millerm@rhodes.edu; 901-843-3556)

We are excited to report the final outcomes of our project designed to revitalize the genetics courses of Pamela Hanson (Birmingham-Southern College) and Mary Miller (Rhodes College). The goals of the project were two fold. 1) To better incorporate active-learning in the classroom by comparing our respective approaches to typical class meetings and adapting each other's best practices for use at our home institutions; and 2) To increase student engagement in the teaching laboratories associated with our respective genetics courses.

Our assessment strategy focused primarily on process and outcome evaluation. The process evaluation approach entailed description of project implementation, description of participating students, and monitoring of the project activities and timelines. To complement the process evaluation, our outcome evaluation methodology focused on assessing the impact of our curricular innovations on student learning and attitudes as well as faculty morale.

PROCESS EVALUATION

In order to attain the goals listed above; this project was carried out in three stages. The first facilitated interactions between P.H. and M.M. and allowed discussion of course design and integration of teaching tools in both the lecture and laboratory sections of the respective courses. The second phase involved implementation of plans during the 2010-2011 academic year. The third and final phase involved assessment and dissemination of our work.

Phase I: During summer 2010, P.H. and M.M. met at two scientific conferences – Genetics 2010: Model Organisms to Human Biology (MOHB) and the Yeast Genetics and Molecular Biology (YGMB) Meeting. At these conferences, P.H. and M.M. developed strategies for integrating each other's best practices in the classroom (goal 1) and increasing engaged student learning (goal 2).

At the MOHB meeting, P.H. and M.M. exchanged classroom materials. Specifically P.H. provided M.M. with a variety of clicker questions designed to gauge student comprehension and identify common misconceptions. M.M provided P.H. with lecture content that goes well beyond the textbook by integrating material from the cutting-edge field of epigenetics – an area of great interest to students and scientists alike.

During Phase I, we also discussed how to increase engaged student learning (goal 2) by integrating teaching and research through our course-associated laboratories, thus providing students the opportunity to apply what they learn in the classroom to a real-world problem. This aspect of the project focused on the challenges of developing effective treatments for cancer. Throughout the laboratory portions of the courses, students took part in guided research projects focusing on characterization of the anti-cancer ruthenium complex indazolium *trans*-

[tetrachlorobis(1*H*-indazole) ruthenate (III)], also known as KP1019.¹ Although early clinical trials of KP1019 are promising,² the mechanism by which cancer cells internalize and are killed by KP1019 is a subject of active investigation. In order to contribute to this on-going line of research, we planned to have BSC students learn techniques to assess growth inhibition, mutation rate, and gene induction, subsequently applying these approaches to yeast strains either lacking or overexpressing genes thought to be modulators of KP1019 sensitivity. To complement this approach, we planned to have Rhodes students examine the impact of KP1019 on the cell cycle and use microarrays to determine which genes are induced or repressed in response to drug treatment. By engaging our students in a *bona fide* research project that is collaborative in nature, we hoped they would experience the excitement of discovery.

At the YGMB Meeting, we continued our lecture and laboratory planning. Importantly, we also discussed our project with faculty members from other primarily undergraduate institutions to obtain their feedback on the feasibility of our course plans as well as our assessment strategy. At both meetings we were able to hear about the latest advances in yeast research, including how yeast can be used as an effective model organism for studying a variety of human medical disorders. During summer 2010, P.H. also collaborated with BSC's Instructional Technologist Jan Pontia to explore appropriate platforms for data-sharing between institutions. Ultimately we chose to develop a PBWorks (www.pbworks.com) wiki to which students and faculty members could upload data and other relevant documents. Overall, Phase I was carried out as proposed, thus providing us with well thought out plans to implement in Phase II of the project.

Phase II: During the 2010-2011 academic year we implemented as many of our plans as possible given several unforeseen scheduling challenges. Specifically, P.H. was unable to implement her updated genetics lectures, because there was an unusually high enrollment which necessitated her to teach more laboratory sections than initially anticipated. Furthermore, M.M.'s section of genetics was postponed until Spring 2011 due to unexpected scheduling demands at Rhodes.

Regardless, we successfully implemented the BSC genetics laboratory changes in Fall 2010 (P.H.) and the Rhodes lecture and laboratory revisions during Spring 2011 (M.M.). This included both the integration of iClicker questions in lectures and KP1019 studies in the laboratory. Furthermore, a wiki designed to allow the sharing of laboratory data between students at the two institutions was developed by P.H., but due to scheduling conflicts described above, we were unable to heavily incorporate the use of this site as a means for student interaction between campuses. Balancing institutional scheduling needs with inter-institutional collaborative exercises is complicated, and more attention would need to be given to this aspect of the project in subsequent years.

Despite these challenges, students at BSC were able to carry out meaningful experiments during the Fall of 2010. Subsequently, during the spring of 2011, Rhodes students built upon the work of BSC students. The work of the BSC students impacted both the experimental design and the

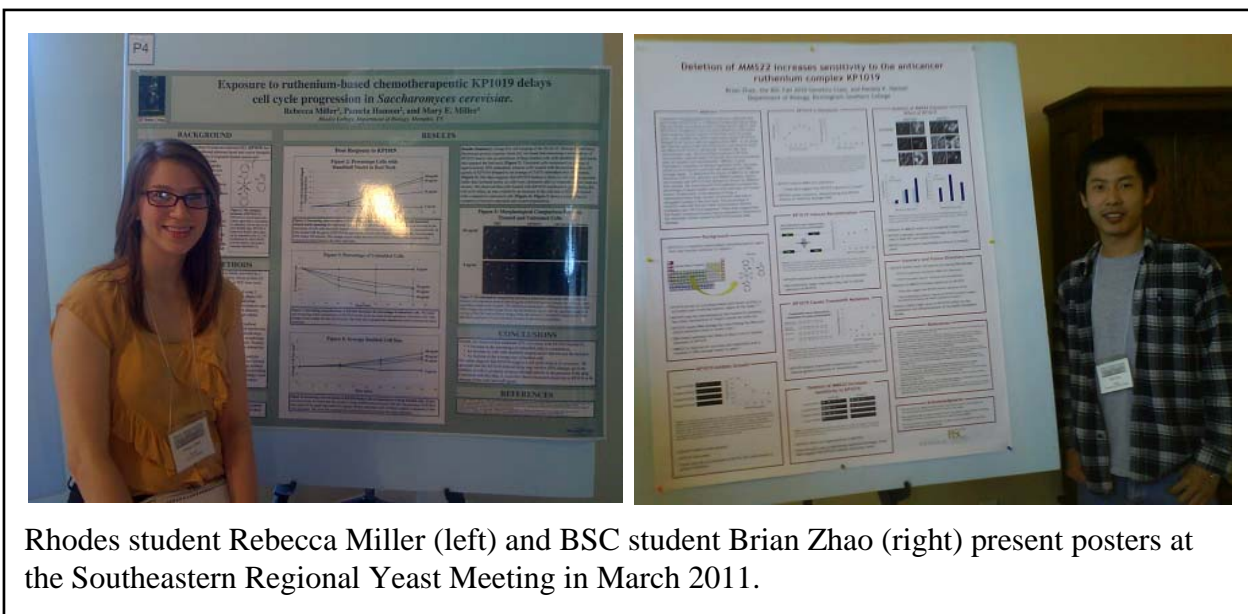
¹ Hartinger, C.G. et al. (2006) From bench to bedside--preclinical and early clinical development of the anticancer agent indazolium trans-[tetrachlorobis(1*H*-indazole)ruthenate(III)] (KP1019 or FFC14A). *Journal of Inorganic Biochemistry* 100:891-904.

² Scheulen, M.E. et al. (2004) A phase I dose-escalation trial with the new redox activated compound sodium *trans*-[tetrachlorobis(1 *H*-indazole) ruthenate (III)]/indazolhydrochloride (1:1.1)(FFC14A) in patients with solid tumors. *Journal of Clinical Oncology* 22:2101.

interpretation of data collected at Rhodes. Furthermore, the data collected by Rhodes students in the spring of 2011 will be built upon by BSC students in the coming academic year (additional details available under “Future Directions”).

During this implementation phase, 62 students were impacted by the revised genetics course at BSC. The majority (56) of these students were juniors, and most (54) were biology majors. Four senior biology majors served as Teaching Assistants for the course and provided insight into student perspectives as well as valuable feedback regarding the strengths and weaknesses of the revised laboratory compared to the activities used in previous versions of the course. The revised genetics course at Rhodes impacted 16 seniors majoring in biology or biochemistry and molecular biology. Directly due to the introduction of iClicker technology supported by this project, iClicker approaches have been incorporated in five other biology courses at Rhodes. In this way, the impact of this project extended beyond the work of P.H. and M.M and impacted the Rhodes Department of Biology as a whole.

Phase III: During the final phase of this project, we assessed the extent to which the outcome goals of the project were achieved. Assessment of our revised laboratories’ impact on students was carried out at each institution at the end of each course. Pedagogical success was evaluated largely based on anonymous, voluntary student feedback and involved institutional evaluation tools (IDEA forms at Rhodes College to assess the overall course, including iClicker impact) and an assessment tool containing questions adapted from an established assessment instrument, namely the Survey of Undergraduate Research Experiences (SURE)³. The modified SURE survey was used at both institutions. In addition to relying on student feedback, assessment of the project hinged in part on instructor observations regarding student attitudes and academic performance in the revised laboratories. Our findings are reported below under “Outcome Evaluation”. In addition to assessing the results of our curricular revisions, Phase III was used to disseminate the scientific results of work related to the project. Specifically BSC and Rhodes



³ Lopatto, D. (2007) Undergraduate Research Experiences Support Science Career Decisions and Active Learning. *CBE-Life Sciences Education* 6: 2297-306.

students presented their findings at the Southeastern Regional Yeast Meeting in March 2011. Additional plans for dissemination are described under “Future Directions”.

Financial Statement: In the original proposal for funding, we anticipated needing \$1613 and \$2001.75 for travel to the Genetics 2010 and Yeast Genetics and Molecular Biology (YGMB) Meetings, respectively. Although we were slightly over budget on these items, we were dramatically under budget for the Southeastern Regional Yeast Meeting (SERYM), in part because P.H. was unable to attend for unanticipated medical reasons. We were also able to implement our laboratory revisions for substantially less than anticipated due to the generous support from our respective institutions. BSC and Rhodes funding for part of our travel expenses (including student attendance at SERYM), laboratory supplies, and iClickers, demonstrate that this project has substantial institutional support, indicating that this project is likely to be sustainable for the long-term. For additional details on long-term plans for this project, please see the subsequent section on “Future Directions”.

Table 1. Budget Summary

Budgeted Item	Requested	Actual		
		Miller	Hanson	Total
GSA Genetics 2010 Meeting	\$1613.00	\$864.77	\$897.76	\$1,762.53
GSA YGMB Meeting	\$2001.75	\$1097.25	\$1890.22	\$2,987.47
Southeastern Regional Yeast Meeting	\$1400.00	\$1067.76	\$0	\$1,067.76
Small Equipment and Lab Supplies	\$2000.00	\$220.22	\$462.02	\$682.24
Total	\$7014.75	3250.00	3250.00	\$6500.00

OUTCOME EVALUATION

The outcome evaluation component of our assessment plan focused on the extent to which the goals of the project were achieved.

Goal #1: *To better incorporate active-learning in the classroom by comparing our respective approaches to typical class meetings and adapting each other’s best practices for use at our home institutions.* Previous studies have shown that incorporation of active-learning strategies, such as clickers, often leads to improved student attitudes and attendance as well as increases in understanding of course content and exam scores.^{4,5} As expected, many of these precedents seem to have held true for the Rhodes genetics class, as incorporation of iClickers increased the number of in-class activities that actively engaged students, while allowing the student understanding of basic concepts to be assessed and student misconceptions about certain material to be highlighted. M.M. found that the iClickers were especially helpful at gauging student comprehension of key concepts, thus allowing her to more intentionally set the pace of her class, spending more time on content found difficult by students and less on subjects perceived as easy.

Goal #2: *To increase student engagement by integrating research into the teaching laboratories associated with our respective genetics courses.* Based on previous reports, we expected that increasing the extent of inquiry in our labs would increase student motivation, active

⁴ Preszler, R.W., Dawe, A., Shuster, C.B. and M. Shuster (2007) Assessment of the Effects of Student Response Systems on Student Learning and Attitudes over a Broad range of Biology Courses. *CBE-Life Sciences Education*. 6:29-41.

⁵ Caldwell, J.E. (2007) Clickers in the Large Classroom: Current Research and Best-Practice Tips. *CBE-Life Sciences Education* 6:9-20.

engagement, comprehension, and sense of accomplishment.^{6,7} Likewise, we anticipated gains in independence^{3,8} and interest in related subject matter^{9,10}, all of which have been reported by others who examined the impact of research experiences and inquiry-based curricula on undergraduates.

As seen in Table 2 (on the subsequent page), our students reported many gains comparable to those reported by undergraduates who engaged in intensive, summer-long research programs funded by the Howard Hughes Medical Institute³. Specifically, students at both Rhodes and BSC reported substantial gains in their ability to analyze data, to interpret results, and to understand science and the research process. Furthermore, Rhodes students reported remarkably high gains on skills in science writing.

When compared to students who conducted summer research³, both BSC and Rhodes students reported lower gains with respect to tolerance for obstacles and readiness for more demanding research. We speculate that these responses are related to one another and derive from the fact that students in our genetics courses were primarily engaged in guided inquiry experiments, wherein the instructors provided detailed protocols. While this approach helped make course-associated research possible, it did remove many of the obstacles associated with truly open-ended research projects. Interestingly only BSC students reported relatively low gains with respect to ability to integrate theory and practice and to understand how scientists think. Although it is difficult to know the exact cause of this discrepancy, one possibility is the diversity of students impacted by the BSC curricular revisions. Specifically, all biology majors at BSC are required to take genetics. Thus, the students enrolled in the course have a broad range of interests, and many prefer field and ecological research to laboratory studies, thus negatively impacting their attitudes and perceived learning gains.

Regardless, it is very impressive that our one semester labs where students met once per week resulted in many learning and attitudinal gains comparable to those obtained by students involved in intensive, summer-long research experiences under the guidance of HHMI-funded investigators. These results point to the powerful impact that may be obtained by integrating *bona fide* research into course-associated labs.

In addition to the self-reported learning gains of our students, M.M and P.H. both observed dramatic improvements in student attitudes toward lab. For example, during an early meeting of the Rhodes genetics lab, students discussed a review article on KP1019, and M.M. noted that students were not only excited, but they were actively engaged in relating the background material on KP1019 to content of a diverse array of courses in biology and other disciplines.

⁶ Wright, J. C. (1996) Authentic Learning Environment in Analytical Chemistry Using Cooperative Methods and Open-Ended Laboratories in Large Lecture Courses. *Journal of Chemical Education* 73: 827-932.

⁷ Deckert, A. A. and L.P. Nestor (1998) An Example of a Guided-Inquiry, Collaborative Physical Chemistry Laboratory Course *Journal of Chemical Education*. 75: 860-863.

⁸ Wenzel, T. J. (2006) General chemistry: expanding the learning outcomes and promoting interdisciplinary connections through the use of a semester-long project. *CBE Life Sciences Education* 5: 76-84.

⁹ Odom, D.P. and M.J. Gossel (2002) Using the two-hybrid screen in the classroom laboratory. *Cell Biology Education* 1: 43-62.

¹⁰ Ramos Goyette, S. and J. DeLuca (2007) A semester-long student-directed research project involving enzyme immunoassay: appropriate for immunology, endocrinology, or neuroscience courses. *CBE Life Sciences Education* 6: 332- 42.

Table 2. Rhodes and BSC Genetics Labs Had Impact Similar to Summer Undergraduate Research Experiences.

Item	Lopatto ^a			
	Overall Means	Colleges Only	BSC ^b	Rhodes ^c
Skill in the interpretation of results	3.83	3.85±0.92	3.80±1.02	3.71±0.73
Tolerance for obstacles faced in the research process	3.99	4.04±0.91	<i>3.44±1.18</i>	<i>3.23±0.83</i>
Readiness for more demanding research	4.03	4.1±0.94	<i>3.41±1.21</i>	<i>3.36±1.08</i>
Understanding of the research process	4.13	4.07±0.92	4.05±0.97	4.07±0.73
Ability to integrate theory and practice	3.78	3.78±0.92	<i>3.46±0.88</i>	<i>3.57±0.76</i>
Understanding of how scientists work on real problems	4.00	4.05±0.91	<i>3.54±1.07</i>	<i>3.64±0.74</i>
Ability to analyze data and other information	3.82	3.93±0.97	3.72±1.02	3.64±0.74
Understanding science	3.63	3.63±1.01	3.50±1.27	3.50±0.52
Ability to read and understand primary literature	3.68	3.70±1.10	3.86±1.07	N/A
Skill in how to give an effective oral presentation	3.42	3.33±1.20	3.41±1.06	N/A
Skill in science writing (preparation of lab reports or papers)	3.32	3.30±1.10	3.38±1.07	<i>3.86±0.95</i>
Understanding of how scientists think	3.62	3.69±0.94	<i>3.24±1.21</i>	<i>3.64±0.74</i>

Values presented reflect the mean gains and the corresponding standard deviations for each item listed. According to the surveys administered 1 = no gain or very small gain, 2 = small gain, 3 = moderate gain, 4 = large gain, 5 = very large gain. ^a Gains reported in Lopatto (2004) *CBE-LSE* 3: 270-277. ^b BSC genetics students were given anonymous surveys at the end of the Fall 2010 semester. ^c Rhodes genetics students were given anonymous surveys at the end of the Spring 2011 semester. Italics indicate BSC and Rhodes values that, according to a single sample t-test, differ significantly ($p < 0.05$) from Lopatto's "Colleges Only" mean.

Positive student attitudes were also apparent in end-of-semester surveys at BSC, wherein 74% of respondents reported that the laboratory experience met or exceeded their expectations, and 70% reported that they were mildly or very satisfied with the experience. In narrative comments 46% made clearly positive statements about the quality of the lab experience, whereas 41% made some sort of complaint about the amount of work required for the lab. Interestingly, many students who found the laboratory activities to be too labor-intensive also reported finding the work to be interesting and/or rewarding. Some representative narrative comments include the following:

- *I enjoyed this lab. I refined the techniques that are used in a molecular biology lab. I felt that the experiments that we were doing were applicable to the "real world", which enhances my learning experience. I also enjoyed the independent project aspect. It helped to develop the skills necessary for creating a unique protocol.*

- *I loved the work with KP1019 because it made lab feel more purposeful and less like busy work. Moreover, the lab was interesting making it a much better experience!*
- *I liked how we studied one specific thing throughout the semester and learned how to test different aspects of it. My favorite part was designing the independent projects though because it required a unique intuitive way of thinking not experienced in other classes.*
- *The structure of the lab with journal clubs, experiments based on those articles, and then guided independent projects was really helpful in grasping the bigger picture.*

Besides improvements in student attitudes, M.M. and P.H. noted substantial improvements in their own morale. The same genetics laboratories had been taught at both schools for several years, thus the new laboratory activities generated excitement, enthusiasm, and a genuine sense of renewal.

Scientific Outcomes: As described in the project proposal, we planned to judge the success of the project not only by the impact of our curricular changes but also by the quality of the data generated by our students. In this regard, we found the data collected by students at BSC and Rhodes to be highly reproducible. Several aspects of the work established by BSC students, including the implication of DNA repair and stress response pathways in KP1019's mechanism of action, were recapitulated in the Rhodes studies. It is important to note that the students did not simply repeat each other's experiments, but rather took distinct approaches to address the same biological question. This broadened the learning opportunities of the students. Given that the experimental approaches used in the two courses were distinct (phenomic analysis at BSC and genome wide transcriptional response via microarray analysis at Rhodes College), the parallel nature of their findings speak to the scientific merit of these exercises. We consider the caliber of the science carried out by the students to be high, and we anticipate with great excitement following these preliminary findings to their logical conclusions in future iterations of this project.

FUTURE DIRECTIONS

Although we initiated the dissemination of our project at the Southeastern Regional Yeast Meeting in March 2011, additional dissemination will occur in the coming year. Specifically, M.M. will present a poster containing student data at the Gordon Research Conference on Chromosome Dynamics in July 2011. Both M.M and P.H. are planning to disseminate their educational and scientific findings at the American Society for Cell Biology Meeting in December 2011. Ultimately, our goal is to publish the results of our curricular revisions in an appropriate science education journal such as *CBE-Life Sciences Education*. Furthermore, once we gather a sufficient quantity of high quality student data, we will submit a manuscript to an appropriate, peer-reviewed scientific journal such as *Genetics*. This broad dissemination plan will ensure that faculty members at ACS and non-ACS schools will be aware of this exciting model for science education, thus allowing them to adapt similar curricular innovations at their home institutions.

Beyond the on-going dissemination of this project, M.M. and P.H. hope to obtain additional extramural funding for this work. In particular, P.H. has collaborated with BSC chemist Dr. Laura Stultz to develop and submit a proposal to the National Science Foundation's Transforming Undergraduate Education in the Sciences Program. If funded, this grant would allow research on anticancer ruthenium complexes to be incorporated into one additional biology

course and two chemistry courses at BSC. In a similar vein, M.M. and P.H. are exploring the possibility of applying for additional funding for the project via the HHMI Undergraduate Science Research Program (proposal due October 2011).

Even if we are unsuccessful at obtaining extramural funds to expand this project and to incorporate higher end technology, P.H. and M.M. plan to continue the collaborative integration of research into their teaching labs. For example, in Fall 2011, genetics students at BSC will follow-up on the Rhodes findings by determining whether the changes in transcript levels identified via microarray translate to changes in protein levels. Furthermore, BSC students will examine the phenotypes of yeast strains carrying hypomorphic alleles of the essential genes shown to be induced in the Rhodes study. Since the results obtained by students at each institution inform the design of experiments at the other institution, gradual and iterative revisions of our respective laboratories will help sustain the sense of excitement and renewal among students and faculty.

SUMMARY

Through this inter-institutional collaboration, students were exposed to the nature of collaborative studies in the “real world”, which energized and deepened their experience. More importantly, they engaged in relevant research on a promising anti-cancer drug. This allowed important discussions not only of “how” research is done, but “why” it is done. Students were able to gauge not only the technical expertise necessary to carry out the research projects, but they also had the opportunity to recognize the potential impact of their work.

A brief summary of the work that may be included on the ACS Faculty Renewal website:

REVITALIZING GENETICS COURSES THROUGH COLLABORATIVE RESEARCH AND SHARING BEST PRACTICES

THIS INTER-INSTITUTIONAL COLLABORATION FOCUSED ON INCREASING ENGAGED STUDENT LEARNING IN THE CLASSROOM AND TEACHING LABORATORIES OF P. HANSON (BIRMINGHAM SOUTHERN COLLEGE) AND M. MILLER (RHODES COLLEGE) DURING THE 2010-2011 ACADEMIC YEAR. RESOURCES INCLUDING iCLICKER EXERCISES FROM BSC WERE SHARED WITH RHODES COLLEGE TO INCREASE STUDENT ENGAGEMENT IN THE CLASSROOM. AN INTER-INSTITUTIONAL RESEARCH-TEACHING COLLABORATION FOCUSING ON THE ANTI-CANCER DRUG KP1019 WAS INTEGRATED INTO THE TEACHING LABORATORIES OF THE GENETICS COURSES AT BOTH INSTITUTIONS. THESE LABORATORY EXERCISES INVOLVED THE EXCHANGE OF DATA SETS BETWEEN INSTITUTIONS, AND THE INTEGRATION OF DATA FROM EACH INSTITUTION IN THE LEARNING EXPERIENCES OF THE STUDENTS. THE EXERCISES WERE DESIGNED TO PROVIDE AN OPPORTUNITY FOR THE STUDENTS TO ACTIVELY ENGAGE IN THE COLLABORATIVE NATURE OF SCIENTIFIC INQUIRY, INCREASING THE IMPACT OF THE LEARNING EXPERIENCE IN THESE LABORATORIES.