Supplemental Material

CBE—Life Sciences Education

Lopatto *et al.*

Supplement Table of Contents

Supplement S1 GEP Faculty Survey preamble

Faculty Survey: Implementation and Sustainability - The GEP Experience

Welcome to the GEP Faculty Survey on implementation and sustainability of the GEP approach to introducing students to genomics research. The GEP is a collaborative effort involving the faculty from many undergraduate institutions. Together we are learning more about the effectiveness of the GEP program, with the hope of guiding others who are interested in bringing research into the undergraduate curriculum. This investigation is funded by the Howard Hughes Medical Institute. It has been approved by the Institutional Review Board at Washington University.

This survey was constructed by Profs David Lopatto (Grinnell College) and Sarah Elgin (Washington University) working from the draft survey developed by GEP faculty members at workshops during summer 2010, and revised by GEP faculty members at the 2011 summer workshops. Begin the survey by clicking the link below. The survey should take about 20 minutes to complete. It is completely anonymous; the data will be collected on a separate website at Washington University, and the composite data forwarded to Dr. Lopatto for analysis. Aggregate data will be reported back to the GEP as a whole for use in funding reports and as the basis for a manuscript written by GEP members.

As with any research, you are not compelled to participate. You may elect not to answer individual questions. A "not applicable" or "N.A." option is available for the questions as an alternative; use this if the question is irrelevant or if you choose not to answer. If you change your mind about completing the survey, just leave the site. It is assumed that the submission of a completed survey is your consent for participation. If you have any questions or comments regarding the survey, please send an email to Prof. Lopatto (lopatto@grinnell.edu).

Thank you for your participation!

Supplement S2 GEP Faculty Survey

GEP Faculty Survey, Spring 2012

1. What year did you join the Genomics Education Partnership? *(alternative buttons)*
   - 2006
   - 2007
   - 2008
   - 2009
   - 2010
   - 2011

2. How many times have you attended a June/August Alumni Workshop? (*alternative buttons*)
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5

3. Are you still an active member? (*alternative buttons)*
   - Yes, I am an active member
   - Yes, I consider myself a member of the group, but I am not using GEP materials at present,
   - No, I am still listed, but I do not consider myself a member of the group; I am no longer teaching with GEP materials.
   - No, I have left the group.

4. If you are no longer an active member, please give the main reason: (*alternative buttons)*
   - Retired, no longer actively teaching
   - Teaching efforts re-directed by my institution
   - Left academia for a different career
   - Dissatisfaction with the GEP program
   - Prefer to direct the research locally
   - Found alternative that is a better fit to my/curriculum needs
   - Not enough time/resources available at my institution
   - Other, N/A

   If dissatisfied or using an alternative approach, please expand: *(comment box)*

5. Which are the best descriptors for your school? *(check all that apply)*
   - A small college (less than 2000 students)
   - A primarily undergraduate institution (no relevant PhD programs)
   - A research university

A minority-serving institution (> 30% minority students)
A school serving first-generation students (> 30% first generation)
A school serving non-traditional students (> 30% over 25 yr old)
A commuter school (> 80% students commuting to school)

6. What was your faculty status when you joined GEP? *(alternative buttons)*
Tenure-track assistant professor.
Tenured associate professor.
Tenured professor.
Non-tenure track faculty member.
Other.

7. What is it now? (*alternative buttons)*
Tenure-track assistant professor.
Tenured associate professor.
Tenured professor.
Non-tenure track faculty member.
Other.

8. Have you co-authored a GEP publication? (*alternative buttons)*
Yes
No

9. Has participation in the GEP helped you to get tenure or a promotion? (*alternative buttons*)
Yes
I think so
No
N/A

10. What was your initial motivation for joining the GEP? *(check all that apply; indicate importance, with 5 being very important and 1 being marginally important)*
This material (genomics) was missing from our curriculum
I wanted to integrate (more) research into our curriculum
I felt that this approach would enhance student learning
I wanted to promote my scholarly interests (e.g. Drosophila, bioinformatics)
I was seeking colleagues interested in genomics education
I was attracted by the opportunity for professional growth
I was attracted by the possibility of publication
My institution encouraged me to participate
N/A
Other (comment box)

11. Why have you stayed as an active member of GEP? (*check all that apply; indicate importance, with 5 being very important and 1 being marginally important)*

Need to keep this material (genomics) in our curriculum
Need to maintain research opportunities in our curriculum
I find that this approach enhances student learning
GEP membership supports my scholarly interests (e.g. Drosophila, bioinformatics)
GEP connects me with colleagues interested in genomics education
GEP membership provides an opportunity for professional growth
We should be publishing soon!
My institution encourages me to continue to participate
Availability of continuing support from central staff
Availability of community support (alumni workshop)
GEP membership makes the project sustainable
N/A
Other (comment box)

12. What was your initial level of utilizing GEP materials? *(alternative button)*
    Use of training materials, problem solving, etc.)
    Sequencing via Chris Shaffer at Washington U.
    Annotation (contributing to research)
    Finishing (contributing to research)
    Finishing plus annotation (contributing to research)
    N/A

13. What level are you using now? *(alternative button)*
    Use of training materials, problem solving, etc.)
    Sequencing via Chris Schaffer at Washington U.
    Annotation
    Finishing
    Finishing plus annotation
    N/A

14. How did you initially implement GEP materials? (*check all that apply)*
    As a module within an existing course/lab
    As independent study
    As a stand-alone course
    As a summer/January semester intensive course
    Other
    N/A

15. How are you using GEP materials now? (*check all that apply)*
    As a module within an existing course/lab
    As independent study
    As a stand-alone course
    As a summer/January semester intensive course

Other
N/A

16. On the scale below, how well do GEP approaches and materials meet your curricular needs for helping students achieve an understanding of eukaryotic genes and genomes

Very dissatisfied	Moderately dissatisfied	Slightly dissatisfied	Neutral	Slightly satisfied	Moderately satisfied	Very satisfied
-3	-2	-1	0	+1	+2	+3

17. On the scale below, how well do GEP approaches and materials meet your curricular needs for introducing students to genomic tools, using computers in biology?

Very dissatisfied	Moderately dissatisfied	Slightly dissatisfied	Neutral	Slightly satisfied	Moderately satisfied	Very satisfied
-3	-2	-1	0	+1	+2	+3

18. On the scale below, how well do GEP approaches and materials meet your curricular needs for providing students with a research experience?

Very dissatisfied	Moderately dissatisfied	Slightly dissatisfied	Neutral	Slightly satisfied	Moderately satisfied	Very satisfied
-3	-2	-1	0	+1	+2	+3

19. What GEP resources or activities helped you to bring genomics research in your courses or curriculum (start up)? (*check all that apply; indicate importance, with 5 being very important and 1 being marginally important)*

Introductory workshop
Alumni workshops
Curricular materials on the web
Central GEP projects
GEP wiki (Table of Faculty, other)
GEP bulletin board (frequently asked questions)
Central GEP staff to help trouble-shoot etc
Other
N/A

20. What GEP resources or activities have helped you maintain genomics research in your courses or curriculum (sustainability)? (*check all that apply; indicate importance, with 5 being very important and 1 being marginally important)*

Alumni workshops

Updated curricular materials on the web
Central GEP projects
GEP wiki (Table of Faculty, other)
GEP bulletin board (frequently asked questions)
Central GEP staff to help trouble-shoot etc
Other
N/A

21. The following items can serve either as incentives or barriers to implementing and sustaining GEP activities. Barriers tend to be dissatisfying; incentives are satisfying. Rate each item for its importance, with 5 being very important and 1 being marginally important; describe the status on your campus when you were first implementing GEP curricula, with 5 indicating that that incentive or barrier was present in abundance, and 1 indicating its complete absence.

	Barriers						Incentives					
Acceptance of genomics in the biology curriculum	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Acceptance of research within the curriculum	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Support from Dept Chair	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Support from faculty colleagues	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Support from staff	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your control over when to offer the course on the calendar (e.g., **fall** semester)	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your control over the place of the course on the weekly schedule (days, time of day, and duration)	N/A	1	2	3	4	5	N/A	1	2	3	4	5
The availability of teaching assistants	N/A	1	2	3	4	5	N/A	1	2	3	4	5
A reasonable teaching load	N/A	1	2	3	4	5	N/A	1	2	3	4	5

The oversight by the college/university via a curriculum committee, etc.	N/A	1	2	3	4	5	N/A	1	2	3	4	5
The quality of IT support	N/A	1	2	3	4	5	N/A	1	2	3	4	5
The availability of computing facilities (e.g., lab rooms)	N/A	1	2	3	4	5	N/A	1	2	3	4	5
The quality of the computer resources (e.g., hardware)	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your expertise in genome-related topics	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your expertise generally in molecular biology	N/A	1	2	3	4	5	N/A	1	2	3	4	5
The alignment between GEP and your research interests	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your experience with *Drosophilia*	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your experience as a research mentor to students of diverse races/**ethnicities**	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your experience as a research mentor to both female and male students	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your overall experience as a research mentor	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Your experience teaching laboratory courses	N/A	1	2	3	4	5	N/A	1	2	3	4	5

Your familiarity with bioinformatic tools	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Adequacy of your programming or other "computer savvy" skills	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Appreciation from undergraduates	N/A	1	2	3	4	5	N/A	1	2	3	4	5
Positive publicity	N/A	1	2	3	4	5	N/A	1	2	3	4	5

22. Additional comments on local implementation: *(text box)*

    What do you perceive as the biggest institutional incentives?

    What do you perceive as the biggest institutional barriers?

23. Additional comments on the utility of central organization; (*text box*)

    Could such genomics research projects be initiated at your campus without access to a central support system, such as the GEP? What are the strengths and weaknesses of having a central system?

Supplement S3 Responses to significant barriers

"What do you perceive as the most significant barrier opposing your efforts to teach genomics by engaging students in research?"

Symbol	Code
	Fit with wider curriculum
	Finding TA support
	Time intensive
	Student interest
	Technical support
	Challenging content
	Institutional buy-in
	Own substantive knowledge

Comment
Consuelo Alvarez, Longwood University, VA: In my school the number of students taking elective classes is small, and thus the competition among all the elective courses makes it difficult to get a high number of students at any given time. (I have enrollments of only 4 to 8.)
Daron Barnard, Worcester State University, MA: Not being able to teach the upper level classes in which I would implement the GEP annotation as the major part of the course as often as I would like is a barrier. Also, a lack of TAs is a problem; during the initial instruction in annotation, 20 students in a class is difficult to manage without a TA. The fact that I cannot teach the class often causes potential "TAs" (we do not have true TAs at my institution) to graduate before the next offering of the course.
Chris Bazinet, St. Johns University, NY: The biggest barrier may be the lack of appreciation within my local community for the importance of training our students in computational approaches.
Dale Beach, Longwood University, VA: The greatest barrier is simply the time required to instruct students and allow them the opportunity to find comfort in the project. Working with the genomics program is time consuming, primarily because the learning curve is much steeper than traditional lab or lecture assignments. Critical analysis of sequence information associated with an active research program is novel for students, in terms of worry that they may make a mistake, and learning to trust themselves to make a valuable contribution. Students need time to learn the techniques as well as to open up to the experience.
James E.J. Bedard, University of the Fraser Valley, BC, CA: The most significant barrier has been the lack of T.A. support. The projects are intensive, and require a lot of one on one time with students. T.A. support would be very helpful with the projects, particularly with larger classes. Since the course is only offered every second year at my institution, T.A. support is limited because those trained may already have graduated by the time the course is offered next.
April Bednarski, Lindenwood University, MO: The biggest barriers would be setting up individual research projects and developing curriculum, but the GEP takes care of both.

John Braverman, St. Joseph's University, PA: The greatest barrier is the time required to train the students to do the annotation project. Fortunately, I can teach the course annually, and have developed or borrowed materials to help with instruction. I do not have any institutional barriers.
Martin Burg, Grand Valley State University, MI: The most significant barrier currently is the issue of class size and whether the class can be taught with the numbers that we currently have, given the amount of time that I spend in the class. A close second is the technical aspect, but with the great support at WUSTL, it really is not a barrier at this point.
Vidya Chandrasekaran, St. Mary's College of CA: One of my main barriers is the lack of TA and other support for the course. Since I do not teach the course every semester, it has been difficult for me to have the continuity of a TA from my previous course to help me with the lab next time I teach it. So, I have to help at least 8 pairs simultaneously and it can get crazy sometimes.
Hui-Min Chung, University of West Florida, FL: The school policy on the enrollment number and the busy required credit hours of our department make it difficult to offer the genomics study (GEP materials) as a regular elective course. I can only offer the course once every two or three years. This also makes it very difficult to recruit and train a TA.
Randall J. DeJong, Calvin College, MI: The most significant barrier is getting a good experienced TA each year who can assist in the laboratory, as well as change-over in faculty instructors assigned to the course.
Justin R. DiAngelo, Hofstra University, NY: The most significant barrier to teaching genomics by engaging students in research is to find enough time in the teaching schedule (my own as well as my Department's) to provide sufficient meeting times for this course to accomplish our research goals. In addition, it is difficult to keep up continuity in terms of my own background knowledge in genomics as well as student knowledge in genomics (in order to find a TA to help with the course) since my genomics course can only run every other year.
Chunguang Du, Montclair State University, NJ: To maintain a good TA supply is pretty tough.
David Dunbar, Cabrini College, PA: The biggest barrier, being at a small PUI, is my inability to teach the course on a yearly basis. Because of our small size, to be fair to other science faculty wanting to teach and/or design upper-level electives, I can only teach the course as a class every other year.
Todd Eckdahl, Missouri Western State University, MO: The most significant barrier to teaching genomics by engaging students in research has to do with the limitations in the expertise of the faculty member. Many GEP members are not actively engaged in genomics research. This makes it difficult for them to provide the expertise needed to teach students how to conduct genomics research in a class that is taught infrequently. However, GEP resources and the GEP community address this difficulty very well. GEP faculty members can use any of a suite of GEP presentations, tutorials, exercises, and software to fill in the gaps in their expertise and engage their students in cutting edge genomics research. And the GEP community works together to raise the level of expertise of all of its members.
Sarah Elgin, Washington University in St Louis, MO: Because I can teach a genomics course every year, I have no trouble recruiting TAs – many students love the project, and are eager to fill this role. However, I teach the course in a writing-intensive style, and take personal responsibility to read the student papers and provide feedback – and require re-writing when needed. This forces me to limit the course to 16

students. If I can figure out how to give individual feedback more efficiently, we could take more students and reduce the wait-list for the course.
Julie Emerson, Amherst College, MA: The most significant barrier is closely related to the most significant incentive, which is the ability to successfully engage sizeable numbers of students in a research project. Student alumni who have the most appreciation for the research mission of the GEP more likely than not were in lower enrollment, upper-level courses or independent projects, during which they had time to think over strategies when new problems arose and could readily obtain assistance and guidance from their instructors. Unfortunately, most introductory courses in biology are survey courses with large enrollments, in which only a fraction of the lab time during the semester can be devoted to GEP projects. Also, student: faculty ratios in lab of 8:1 (or higher) make it difficult to efficiently help students when they encounter new problems.
Amy Frary, Mount Holyoke College, MA: Because our department is small, my teaching responsibilities are broad and I can only offer the course alternate years. This means that finding a student TA is difficult.
Don Frohlich, University of St. Thomas, TX: Far and away our two biggest problems are time for instruction (outside of the classroom) and my own expertise. Our only other faculty member involved in genomic research works on bacteria, and I actually work in evolutionary and population biology. Admittedly, I need to make a sustained effort to collaborate or stay in contact with other GEP members. Our other large problem is actually convincing students bound for medical school that a genomics approach will very much be a part of their professional futures. This problem seems to be waning, however.
Anya Goodman, Cal State University-San Luis Obispo, CA: The most significant barrier for me is the workload, more specifically, the lack of time. Curriculum based on research projects does not scale the same way traditional labs and lectures do. I need to engage in dialog with every student every class meeting. I cannot do that in a large class. My limit right now is 24 students and even that is too high without a teaching assistant. There is institutional pressure to increase class size (mine went from 16 to 24) or risk the course being canceled. Compared to traditional teaching, a lot more work goes into guiding students through research projects; this adds to an already significant workload, juggling teaching, other research and service. Ultimately, the barrier is lack of recognition of how valuable research experiences are for students and how much work goes into creating these experiences.
Yuying Gosser, Grove School of Engineering, The City College of New York, CUNY, NY: The conventional definition of the biology curriculum, which has been deeply rooted in most faculty and administrators, hinders adoption of a genomics research course.
Shubha Govind, Biology Department, The City College of New York, CUNY, NY: Having to contribute to the departmental core courses limits time for this work.
Adam Haberman, Oberlin College, OH: Student misgivings about sequence improvement projects – due to complex software and projects that seem confusing to novices – has limited participation.
Amy T. Hark, Muhlenberg College, PA: While having students working on individual projects requires more investment of my time than simply lecturing on genomics, it is so much more rewarding for both me and my students that it is worth the effort.
Charles Hauser, St. Edward's University, TX: Being a small bioinformatics program requires that I recruit students from other departments for the course to make enrollment limits, which makes teaching the course on a regular schedule problematic. From an infrastructure point of view, I am lucky in that the COSC

department provides access to UNIX servers, which run the software for finishing (Consed/phred/phrap).
Arlene J. Hoogewerf, Calvin College, MI: The most significant barrier is having enough students who are familiar with the annotation project to serve as TAs in subsequent years.
Diana Johnson, George Washington University, Washington DC: Time is the biggest barrier. I have much more I would like to teach than I have class time in which to teach it.
Christopher J. Jones, Moravian College, PA: On the finishing side, it's technical: our IT people do the best they can balancing the demands on their time, but troubleshooting the installation of the Consed/phred/phrap suite always takes away a noticeable chunk of class time. In contrast, annotation has always worked well; the closest thing to an obstacle is the perception of some students that this isn't real research. That's changing as students become more familiar with genomics in other contexts (e.g. other classes, news items), and I try to underscore this in the course.
Lisa Kadlec, Wilkes University, PA: As others have said, a major barrier is time. While my department has been supportive of my participation in the GEP, there really isn't a good place in the curriculum into which to slot a full genomics course, and so I integrate genome annotation as part of the lab component of my upper-level elective in Genetics. I think this works, but it can be difficult to fit everything I feel the students need into the available time frame. That said, I appreciate the flexibility of the GEP in terms of implementing the material and I think I've found a fairly happy medium in terms of fitting genome annotation into my existing course and giving the students a meaningful experience. Finding TAs can also sometimes be a challenge. While my genetics course runs every fall, if I have a senior-heavy group I don't necessarily have a pool of students from which to try to recruit a teaching assistant.
Marian Kaehler, Luther College, IA: Time, time, and time are the first three issues. The rapidly changing details involved in using the websites is a bit of a hassle, but the most important difficulty is the fact that annotation as a research experience requires intensive mentoring. We are over-enrolled, so it is nearly impossible to convince the Dean that these types of low-enrollment courses are required to achieve the outcomes we desire.
S. Catherine Silver Key, North Carolina Central University, NC: I perceive that the most significant barrier to teaching genomics by engaging students in research is the restricted time-frame imposed by my choice to insert genomics as a module within a required course for Biology majors. While my enthusiasm for research-based learning is strong, my teaching load is heavy and for reasons of self-preservation, I have refrained from implementing a complete Genomics course at my institution.
Nighat P. Kokan, Cardinal Stritch University, WI: It is challenging to teach genomics and annotation with the constant updates to the websites. Some students do not like the open-ended nature of the research projects.
Olga Ruiz Kopp, Utah Valley State University, UT: The most significant barrier is keeping a good TA to help with the new students. Most students in our school work to support their families, and sometimes they cannot commit themselves for long periods of time. Instead, I used modules or part of the GEP information that I can also use in other lower division courses to take advantage of the wonderful service GEP provides.
Gary Kuleck, University of Detroit Mercy, MI: Time constraints have always been challenging. With a heavy teaching load, other research responsibilities and often lacking trained TAs, it is difficult to bring the necessary time and

focus to allow work to proceed outside the teaching laboratory periods. Nonetheless, having enthusiastic students interested in research makes it easier to make time.
Christy MacKinnon, University of the Incarnate Word, TX: I have found no significant barrier.
Juan C. Martínez-Cruzado, University of Puerto Rico at Mayagüez, PR: I engage students in this research by means of a special topics course. The most significant barrier opposing these efforts is that I must have a minimum of 15 students registered in the course.
Gerard McNeil, York College, CUNY, NY: The greatest barrier to successful implementation to this effort is being able to schedule enough time to do everything that I would like to do in the class. Currently I have two, two-hour slots to teach a course in bioinformatics where they do both finishing and annotation. This is barely enough time for the student to learn the techniques and solve the research problems. I would like more time to go over how to solve certain types of problems and to discuss relevant literature.
Stephanie Mel, University of California, San Diego, CA: Due to recent budget cuts, offering a class for just 20 students is currently not a viable option -- I am needed to teach much larger classes full-time. I am working to incorporate elements of GEP into our large undergraduate lab classes, but this has been challenging to do as there are multiple sections taught by different faculty members.
Alexis Nagengast, Widener University, PA: The biggest barrier is time. I would love to be able to offer Genomics as a stand-alone course or even as part of a lab course every year, but my teaching load won't allow it. There are too many high enrollment non-majors courses that need to be taught instead.
Paul Overvoorde, Macalester College, MN: Prior to the formation of the GEP, the largest challenge was a connection to a relevant data set. Although I am not a Drosophila geneticist, a connection to a relevant research question that can be addressed through the process of genome annotation provided a framework for making use of the growing number of sequenced genomes.
Don Paetkau, St Mary's College, IN: My biggest barrier is the lack of access to the Wash U Genome Institute finishing pipeline during the fall semester, as the demands of the department force me to teach this course in the fall.
Susan Parrish, McDaniel College; MD: The most significant barrier is having the available laboratory time to complete the projects. I am fortunate that my department has been supportive in allowing me to add a laboratory component to the Genomics lecture course.
Mary Preuss, Webster University, MO: Lack of time is the biggest barrier. This is done on top of my normal teaching load/professional development/service, so finding the time to either teach a new course or train new students in independent research can be challenging. However, the resources that are provided by the GEP help enormously. I could not do this without the GEP.
Laura K. Reed, University of Alabama.-Tuscaloosa, AL: Thus far for me the two greatest barriers have been (1) technological (inadequate Wi-Fi bandwidth in the classroom for students to reliable work on their own laptops and a lack of modern university-supplied computers in the classroom) and (2) a lack of student preparation in basic concepts in genetics and evolution before they enter my classroom.
E. Gloria Regisford, Prairie View A&M University, TX: The greatest barrier for me is the limited time that we have to complete the projects. Students who are enrolled in a 1-credit Research class are engaged in annotation. They do go

over and beyond the 1 hour every week, but more could be done if students could get credit for a 3 hour class.
Dennis Revie, California Lutheran University, CA: The first barrier was getting the finishing program (Consed) up and running, as our computer specialists knew nothing about UNIX/Linux platforms. The current barrier is finding the time to teach the class. Our Biology enrollment has mushroomed, so we have to teach "core" classes more often. This leaves less time for Genomics.
Srebrenka Robic, Agnes Scott College, GA: The first barrier is the inability to teach the course on an annual basis. This makes it difficult to find students to serve as mentors/TAs for the course. The second barrier is a lack of IT support and available technology. That is the primary reason why I decided not to continue with the gene finishing part of the project, which requires a UNIX platform.
Jennifer A. Roecklein-Canfield, Simmons College, MA: One significant barrier is finding space in an already full curriculum to include the material. I've modified two separate courses to include GEP but do not have the luxury of a stand-alone course. It would be wonderful to have a semester long course to cover bioinformatics tools and research. Another issue that sometimes arises has to do with the preparedness of the students. Often the students in the class have not all taken the same set of background courses. It is sometimes difficult to find a balance in level of content so as to not bore the students with previous genetics experience, but keep it simple enough for the students who have not studies genetics.
Anne Rosenwald, Georgetown University, Washington DC: I have not encountered significant difficulties.
Michael R. Rubin, University of Puerto Rico at Cayey, PR: One significant barrier opposing efforts to teach genomics by engaging students in research is the slow process required to implement curricular changes. Another barrier is resistance to change and innovation by some educators. The lack of infrastructure including computer facilities with readily available rooms containing sufficient workstations to accommodate increasing class sizes is also a barrier.
Ken Saville, Albion College, MI: One barrier for me is a lack of Mac-based or Linux-based computers at our school. This is a limitation for doing the sequence improvement portion of the course, as the Consed software does not run on a PC system. There are mechanisms to overcome this, but they add an additional start-up barrier to taking part in that aspect of the project. A previous barrier was having students with a wide variety of backgrounds taking the course. We have restructured our curriculum so all students will have completed genetics before taking this course. This makes it easier to teach. I have encountered very few institutional barriers, other than generally trying to fit the course in, and generating student interest.
Stephanie Schroeder, Webster University, MO: My main problem has been the minimum number of students needed for a course to run. The Gene Expression class is now offered every other year, which has also made it difficult to maintain momentum with teaching assistants.
Karim Sharif, LaGuardia Community College, NY: At a community college, a full course in genomics cannot be offered. We implemented GEP as an independent research study. However, there is no provision to compensate students engaged in research with stipends, which would enable students to spend many more hours in the research, rather than working elsewhere to meet their financial needs. GEP sustainability also becomes a challenge when a trained student opts out owing to increasing personal financial needs, adding to the faculty time demands in training new students.
Mary Shaw, New Mexico Highlands University, NM:

My main problem is in engaging students and getting them interested in the project. They want to do wet lab research in something that has direct practical application.
Gary Skuse, Rochester Institute of Technology, NY: Our most significant barrier involves obtaining sufficient enrollments to make our course viable. Students recognize the value of the course, but they have difficulty fitting seven hours of computer laboratory time into their weekly schedules. If an insufficient number of students enroll we cannot offer the course, but we are addressing this challenge in two ways. First, we offer the course during alternating years in an effort to combine interested students into a single class with sufficient numbers. Second, we advertise the course as a natural follow-on to a genomics course that is required for students in some of our programs. Together these efforts appear to be working.
Mary Smith, North Carolina A&T State University, NC: My department is supportive of teaching genomics and bioinformatics. The major barrier is the lack of exposure of students to genomics and bioinformatics in previous courses. It takes time to introduce students to so many tools and then have them use those tools to answer a real research question. Thus students are initially frustrated because the content of the course is so new, and the approach to teaching and learning is a unique experience for them. Having a teaching assistant is very important in alleviating some of the frustration. Without that support, it is difficult for a single instructor to address the problems that different students encounter during a class period.
Sheryl T. Smith, Arcadia University, PA: I don't feel that we have significant barriers to teaching genomics through research at Arcadia. We have broad support from the Biology and Computer Science/Math Departments for using this approach and have been provided with great technical support. The only barrier is that we have one computer lab that can accommodate approximately twenty students, so we are limited as to the number of students that can enroll in the course. Also, with twenty students, we would ideally like to have two additional TAs, which may not be possible.
Eric Spana, Duke University, NC: I've found the most difficult problem is finding a sustainable computational solution. Every few years, the University changes its mind on how/what/where computer classrooms are available. This makes every iteration of the course a new hassle in course location politics.
Mary Spratt, William Woods University, MO: Most of our upper division biology classes have been offered only every other year. This means that even TA's tapped as juniors will have graduated before the course is offered again. This also slows down the momentum of instituting research for all students. Another problem is the need to teach Genomics within the context of another course, which already has a full topical load and for which there have been no preparatory courses. Lack of IT support and the need for upgraded computers have also been problems.
Aparna Sreenivasan, Cal State University-Monterey Bay, CA: My course that incorporates research in the classroom fills on the first day that class enrollment opens. So there is clearly a need. But I think that we need a course directly preceding my course that provides background in bioinformatics and genomics so that I could bring my course to a higher level. I also do not have any technical support at my university, so without the GEP structure, I wouldn't be able to teach my course as well - and /or would be constantly figuring out how to use the materials.
Joyce Stamm, University of Evansville, IN: My biggest hurdle has been scheduling for my stand-alone Genomics course. I have changed class meeting times (how often and for how long) each time I've taught the course, and haven't been completely satisfied with any of the schedules. I would love to have more class time so that the students can comfortably complete the finishing and annotation projects AND explore

the relevant research literature, but more class time means more conflicts with other courses, which can exclude students from the course.
Jeff Thompson, Denison University, OH: There are two notable challenges that I typically encounter. The first is with respect to convincing students that working at a computer is "doing research." Many students view research as being something done at a bench or in the field, not working with computational information. Second, the annotation projects can at times become a bit monotonous from a technical perspective, and it requires an extra effort on my part to keep them intellectually engaged in the exploration.
Matthew Wawersik, College of William and Mary, VA: Genomic research is best taught with a low student to teacher/TA ratio, since use of genome analysis programs/web sites can be difficult to maneuver. However, because students taking this course are often Juniors or Seniors, it is difficult to find TAs before they are ready to graduate.
Michael Wolyniak, Hampden Sidney College, VA: Our students tend to be hung up on the idea that "research" is in fact not actually "research" unless it involves test tubes and beakers. One of the challenges of teaching genomics is to overcome this prejudice and to show them the importance of computer-based bioinformatics work as a needed companion to the bench work that students more freely associate with science.
Jim Youngblom, California State University – Stanislaus, CA: The course can not be taught in the same way each year- it undergoes necessary changes and course improvements every time I teach it. The database entries change and new tools are available for analysis every year. My practice labs need annual revision or overhaul and I need time to learn how new information and tools should be integrated into the curriculum.
Leming Zhou, University of Pittsburgh, PA: Since my students are not in a biology major, it takes me significant efforts to explain the importance of understanding genomics and genomic data processing in their future careers (managing personal health data).

Supplement S4 Responses to support system

"Is a central support system (i.e., a centrally organized research project, shared training curriculum, central IT support) of continuing importance for your teaching genomics?"

Symbol	Code
	Access to significant research
	Access to teaching resources
	Access to scientific expertise
	Access to technical support
	Access to community

Comment
Consuelo Alvarez, Longwood University, VA: Definitely – a central support system greatly helps at my small institution. In addition, the centralization allows for good interactions among faculty peers and students who are working on the same project, which stimulates the students to learn the new techniques and approaches needed.
Daron Barnard, Worcester State University, MA: This continued support is vital to the continued implementation of our research-based lab. The centralized project holds us together with a focus that I feel might be lost if the project became more diverse. I say that even though my other research is in another direction; this focus allows the shared curriculum and support, both IT and scientific.
Chris Bazinet, St. John's University, NY: The central support from the GEP project is absolutely essential to the local success of our project. The training sessions at Wash U for faculty and teaching assistants, the organization of the project into modules/units students can work on, the setup of a centralized system for recording data, and the availability of expert IT help dedicated full time to making the system work are all things that could not be replicated at my home institution. My students would still be doing "canned" web exercises, unconnected to any real research projects, if GEP resources were not available.
Dale Beach, Longwood University, VA: The GEP community is vital to continuing the genomics education program that we have at Longwood. First, it provides the resources and structure to coordinate and develop the "ranked" project system that allows me to introduce topics with easier "green" projects, and subsequently push advanced students in to the more difficult "red" projects. I would not necessarily have the time to create these projects without the program, even a single model project that would be redundantly reviewed by all of my students. Second, the community provides the professionalism and expertise for both experimental and pedagogical development. As a support network, I know that I can fall back on the collective knowledge of the community to help solve problems and ask new research questions.
James E.J. Bedard, University of the Fraser Valley, BC, CA: Yes, a centralized support system is absolutely essential to my university's ability to continue offering high quality genomics instruction. Our institution is primarily an undergraduate university with limited funds for individual student research projects. The GEP has been instrumental in bolstering the quality of genomics education and research. Without a central support system, the enhanced student-focused research would be difficult to sustain for a large

number of students. The GEP provides access and support for collaborative research opportunities to small undergraduate institutions with limited research capital. A centralized approach allows for sharing of resources, which would not be accessible to any single undergraduate institution on their own.
April Bednarski, Lindenwood University, MO: Without the central support system of the GEP, the research aspect of the curriculum would stop in my course. I would still teach the introduction to annotation with the help of the existing GEP curriculum, but the students would no longer have a research project. This would greatly affect student interest and learning. The set problems don't allow students to have the experience of discovery, which really makes this more than just a course to them.
John Braverman, St. Joseph's University, PA: The centrally organized research project really helps me. The GEP provides the raw materials and context for this work. I feel it is intellectually satisfying to annotate knowing we are contributing to an interesting genomic-scale question about heterochromatin. There is plenty to discuss and work through in the network (including our local Philadelphia-area meeting) and then at alumni workshops. As for IT, fortunately the GEP materials and projects mainly require a web browser. So my local computer labs, as well as students with their own computers, are sufficient.
Martin Burg, Grand Valley State University, MI:. Yes, the shared system is essential, as I would not have the expertise alone, nor the time, nor the energy to put together what the combined efforts have accomplished in the several years that I have been involved with the GEP. I have recruited two other faculty members at GVSU to incorporate GEP related exercises in the genetics and bioinformatics classes that do already exist. While I have been able to get a small group established, I do not believe that I would be teaching the course that I do teach without the centralized GEP web management and the team behind that. It is very clear that a centralized organization does enable those with interest to assist in a project by providing the 'students' for the overall project. Having another 'person' or 'center' to submit projects to also provides participating students the reality check that they are doing something real, and the tools that the GEP has come up with to complete and manage projects makes this an easier task to accomplish.
Vidya Chandrasekaran, St. Mary's College of CA: The centralized support system is important for me to be able to implement a research-based genomics course. We do not have the IT expertise in house to design a submission system and maintain a project of this magnitude.
Hui-Min Chung, University of West Florida, FL: The central support system is vital; it not only provides training and services, but also the means for double checking our results. Without the central system, it is unlikely that we would achieve any publishable results.
Randall J. DeJong, Calvin College, MI: The centralized support system is essential because most faculty do not have the time nor the skills to make the data accessible, create the submission system, do the checks, and write training materials themselves. The central site is also important in that it provides the students with a professional, well-done introduction to the collaborative aspect of the science.
Justin R. DiAngelo, Hofstra University, NY: The central support system at Washington University is by far the MOST essential requirement for teaching genomics in this fashion. Without the support provided by the folks at Washington University (in terms of project management, curriculum development, and the web interface/tools), I would NEVER be able to teach genomics by engaging students in research.
Chunguang Du, Montclair State University, NJ: My students have been annotating the DNA sequences generated from my NSF project. I

find the annotation teaching materials are very useful to my students.
David Dunbar, Cabrini College, PA: To me, it is of upmost importance to have a centralized system with a lead scientist!! Small institutions such as Cabrini College simply do not have the resources to sustain such a research-intensive enterprise on their own. I might be able to do so on a much smaller scale but would not be nearly as productive in pedagogical publications and scientific publications as can come out of the GEP program. Since we are a small PUI, we would never have the N number of students to show convincing assessment data for institutional administrators or granting agencies. Plus it is invigorating to both faculty and undergraduate students to see "big science" and to be part of a project much bigger in scale than the course or instructor at a small institution.
Todd Eckdahl, Missouri Western State University: The GEP central support system is critical for the success of faculty members teaching genomics research to undergraduate students. Especially when the faculty member is not actively engaged in genomics research, or lacks expertise and training in this area, GEP central support is essential.
Sarah Elgin, Washington University in St. Louis: Having a collaborative system involving many schools allows us to make progress on much larger projects than would otherwise be possible, allowing the students to make a unique contribution. Having the input of many faculty members results in a much richer teaching environment than can be generated by a single faculty member. And it is only by pooling our efforts that we can test this approach at a diverse set of campuses, with a large enough student population to generate useful assessment.
Julia A. Emerson, Amherst College, MA: A central support system is absolutely essential for teaching and research in genomics using GEP materials. The GEP Web site makes it easy to claim ~40 kb projects for sequence improvement and/or annotation and also to upload all data files once the research analyses are completed. The GEP staff members at Washington University in St. Louis are also easily reachable by e-mail or telephone, and detailed answers to questions are always returned within 24 hours, if not immediately. Finally, the GEP Wiki page is a great way to see how other faculty are using GEP resources in their courses, which is helpful for annual revisions of our labs.
Amy Frary, Mount Holyoke College, MA: The support provided by GEP has been essential. Without the training workshops and curricular materials, introducing new gene annotation labs into my course in molecular evolution would have been too daunting a task.
Don Frohlich, University of St. Thomas, Houston, TX: Absolutely! We (I) cannot engage in a genomics approach to biological research without central support. Even though we are surrounded by one of the world's largest medical centers (including three medical schools), we do not have the sequencing and data base management skills, or the resources, provided by GEP. The entire project gives our students and faculty access to a unique "complete package" available to few others.
Anya Goodman, Cal Poly State University, San Luis Obispo, CA; Yes! 1. Having a community of faculty working on the same pedagogical challenge is essential to our success. For many (most?) faculty members in the GEP community, there are no other colleagues on their respective campuses engaged in this mode of teaching. Discussions of our experiences in implementing the curriculum and mutual support during alumni meetings help solve the challenges we encounter. 2. Genomics is such a rapidly developing field, it would be difficult for most teachers to keep up while pursuing all the other commitments in teaching, professional development and service. Having central organization

that helps us keep on top of new research, computational tools and pedagogical approaches is essential. 3. In a course setting, our primary goal is student learning; the research component enhances the learning, but we cannot expect large-scale contributions from the beginning researchers. Therefore, significant research goals can only be accomplished by aggregating small contributions from a large number of students.
Yuying Gosser, Grove School of Engineering, The City College of the New York, CUNY, NY: The leadership of the GEP is critical in enabling me to teach a research- oriented, web-based genomics & bioinformatics course to science and engineering students, since this type of course is non-traditional and is still struggling to find its ground in the conventional curriculum of individual science and engineering majors. GEP brought cutting edge research education to classrooms, which has elevated biology education in many colleges. GEP has gathered a "critical mass," that will play an important role in revolutionizing biology education. The GEP leadership is demonstrated through the central support system at Washington University at St Louis.
Shubha Govind, Biology Department, The City College of New York, CUNY, NY: We need to diversify teaching methods, but for GEP, yes, we need the central support.
Adam Haberman, Oberlin College, OH: A central support system is essential for my teaching genomics using research projects. Some parts of these projects fall outside of my training, and the existence of support staff makes tackling these projects feasible. Also, I have needed IT support to prepare computer labs for two years in a row.
Amy T. Hark, Muhlenberg College, PA: A centralized system is vital for coordinating efforts for publication, and the opportunity to contribute to a productive research program is one incentive to keep teaching genomics in this manner.
Charles Hauser, St. Edward's University, TX: Absolutely. Without the centralized support, training, tool development, and project feedback, engaging students in this level of research would be problematic.
Arlene J. Hoogewerf, Calvin College, MI: A central support system is very important for teaching genomics because it provides access to annotation projects in "chunks" that are appropriate for undergraduate students during a one-semester course; and the training materials that others have provided allow students to have richer training materials than if they were developed by a single individual.
Diana Johnson, George Washington University, Washington DC: The GEP support system is what makes this possible. These projects can be complex and I can be unsure how to proceed. The training provided and the continuing support are both essential in making the project work. Further, the sharing with other faculty and the learning of new ideas and approaches to this project have enriched my teaching experience, and my teaching in general.
Christopher J. Jones, Moravian College, PA: The GEP's central support system is absolutely essential to my continuing to teach genomics. As projects are finished and new genomes are brought "on line," new problems arise in both genome finishing and annotation. Without a knowledgeable central staff to coordinate the updating of materials to reflect these changes, it would become impossible to effectively engage students. If we weren't to take on new challenges, the course would rapidly become a stale re-hashing of known genomes, removing the challenging novelty that I think is critical for engaging students so effectively. On the other hand, analyzing new genomes without that central support would result in our rapidly hitting insurmountable walls: GEP "headquarters" makes it possible and efficient to coordinate the identification and resolution of the novel obstacles each genome project presents. Having many participants makes it possible to

relatively easily make a major impact on both student engagement and scientific progress. The energizing balance between the challenge and excitement of exploring the unknown and the inevitable frustrations encountered is kept in play by the central support system that GEP has, and that has (for me) made all the difference.
Lisa Kadlec, Wilkes University, PA: The central support system provided by GEP is really an essential part of my being able to offer the sort of hands-on experience of an up-to-date research project that my students currently enjoy. While I could continue to teach this material on some level, having such a knowledgeable central staff updating materials, keeping resources up to date, and providing new core projects upon which I and other GEP members can collaborate, allows me to continue to engage students in a more meaningful way. Also, the summer workshops provide a great opportunity to refresh/update my own skills and knowledge, and reconnect with colleagues working toward similar goals.
Marian Kaehler, Luther College, IA: Even with a lab exercise (rather than a research-based experience), the GEP website offers incredible support for all levels of implementation. If doing ongoing research-based courses, the availability of a central support system such as the GEP site at Washington University is essential. The personnel at WU have been extraordinarily generous with their expertise and support.
S. Catherine Silver Key, North Carolina Central University, NC: Absolutely! The central support team is ESSENTIAL to my continued teaching of the research-based genomics portion of my didactic Genetics course and my non-didactic Introduction to Research course. Many times I have run into questions that can only be resolved with GEP central. Genomics is a rapidly evolving field and keeping pace with it requires 100% devotion by experts in the field. As a genomics neophyte with next to 0% time, I can only attempt to bring this wonderfully engaging genomics research opportunity to my students at NCCU through the efficient, infinitely patient, and knowledgeable team at Washington University in St. Louis.
Nighat P. Kokan, Cardinal Stritch University, WI: The GEP central support system is extremely important for my continuation of teaching genomics research to my students. The curriculum materials, supporting documents with the updates and the access to technical expertise of GEP staff are critical to teaching genomics at my institution.
Olga Ruiz Kopp, Utah Valley State University, UT: Yes, the GEP support is vital for teaching genomics either as a distinct course or as a module in other courses. There is excellent information available, including shared training curriculum for all of us to use. The resources and structure provided by GEP are essential for the success of the genomics course.
Gary Kuleck, University of Detroit Mercy, MI: The central support is absolutely critical to teaching genomics using authentic research projects. Having a dedicated central support system makes it possible for those of us not trained as graduate students or post-docs in bioinformatics and genomics to carry out these projects to benefit of both the students and the faculty.
Christy MacKinnon, University of Incarnate Word, TX: The GEP support system is essential to implement research projects. I could not do the research projects without it! The "one-stop" GEP website is very easy for me and for my students to navigate. The Faculty Workshop and subsequent Faculty Alumni Workshops have been essential for me to keep up with changes in bioinformatics, including the GEP system, and have enabled me to network with colleagues.
Juan C. Martínez-Cruzado, University of Puerto Rico at Mayagüez, PR:

We are now annotating the Puerto Rican parrot genome. However, in order to train incoming students in genomics, we spend about half a semester annotating Drosophila genomes BECAUSE of the GEP support. It is far easier and more effective to teach students when you have resources such as the UCSC Genome Browser and the Gene Model Checker rather than starting from scratch, which is the case for the Puerto Rican parrot genome.
Gerard McNeil, York College, CUNY, NY: Having the central support system at Washington University is critical to the success I have had. Although we could teach some of the skills alone, the entire research experience would not be possible without the support of those individuals. The ability to give students their own projects, that will become part of an overall large project, is critical to the students feeling of accomplishment and of the importance of their work.
Stephanie Mel, University of California, San Diego, CA: Yes! It would have been impossible to set up my course and to run it without the help of the GEP team. This includes the tools that I picked up at the workshops, as well as the online help provided. The material is complicated for students and having the strong support of the GEP team allowed us to troubleshoot and move forward with our annotation projects much more effectively than we could have done on our own.
Alexis Nagengast, Widener University, PA: Absolutely. I don't think I could do an effective job on my own without the framework of the GEP supporting me. I definitely would not be able to have students participate in a research-based project and contribute to the greater body of scientific knowledge without GEP materials. The research aspect of the annotation and potential for a professional publication is one of the main reasons students take my class. I wouldn't be able to do that on my own.
Paul Overvoorde, Macalester College, MN: Yes, most definitely. This central organizing system allows research questions addressed in parallel by many undergraduate students to be crosschecked and compiled. The ability to use prepared projects provides useful chunks of new material for the classroom. In addition, the computational support enables web-based software and genome editions to be continually updated, which saves time and benefits all GEP participant institutions.
Don Paetkau, Saint Mary's College, IN: The centralized support is absolutely required for teaching this course. From technical help with the initial Consed set up, to weekly Forum/staff questions, to the teaching discussions with colleagues, to the collaborative progress toward an interesting research goal, to the energizing work during the summer sessions, to the constant updates to make things run smoothly, this course works because of the centralized support and the support for colleagues to directly interact with one another. The summer work especially provides each individual teacher with the ownership of this course that makes it possible to invite their students to be part of this research project with enthusiasm and confidence.
Susan Parrish, McDaniel College, MD: The GEP centralized support system is absolutely critical to the success of the program, to provide answers to questions, to consolidate annotation projects, and to bring both the pedagogical and scientific data to publication readiness.
Mary Preuss, Webster University, MO: The centralized support system is crucial to being able to continue these research projects. From start to finish the GEP system enables the curriculum, provides troubleshooting, and brings it all together into the big picture for students and the scientific community to see.
Laura K. Reed, University of Alabama.-Tuskaloosa, AL: I rely heavily on the resources provided by the GEP in teaching this component of genomics research in my course. Without the centrally organized research project, curriculum, and IT support, I think I would find it difficult to continue to provide this opportunity to my

students, given my time obligations to other professional activities, such as my own research.
E. Gloria Regisford, Prairie View A&M University, TX: A central support system is absolutely essential for an institution like ours, where research access is limited. The annotation research projects, the troubleshooting and fundamental curricular resources are instrumental in the success of our program.
Dennis Revie, California Lutheran University, CA: My local computer support system has not been much help. The GEP computer support is very important: I sent a computer to Washington University to be set up correctly. Since then I've been updating software myself. However, glitches that occur sometimes require help from the central GEP support team.
Srebrenka Robic, Agnes Scott College, GA: The central support system is absolutely crucial for me. It was easier for me to get help from the central GEP IT support all the way at Washington University than from my home institution's IT team. I benefited tremendously from the training workshops, and I continue to learn by using the tools, databases and curricular resources available on the website.
Jennifer A. Roecklein-Canfield, Simmons College, MA: The central system is absolutely vital. Having a central repository of curricular materials is invaluable. The amount of time it would take a single or a few faculty members to amass this collection would make it impossible. In additional, having access to resources for implementation, such as the GEP staff themselves or other faculty using the materials, is a huge advantage. The support of the community is pivotal to successful operations in the classroom.
Anne Rosenwald, Georgetown University, Washington DC: For a project of this size (>100 faculty, >1000 students) a central support system to define the questions and organize the information is crucial.
Michael R. Rubin, University of Puerto Rico at Cayey, PR: The central support system provided by the GEP is excellent: in organizing the projects, providing easy-to-use education and support resources, providing student research opportunities and publication possibilities, and offering readily available and easily accessible help when needed. The initial training and follow-up meetings for faculty at Washington University have been excellent in organization and extremely helpful as a forum for genomics instruction, relevant pedagogy, and networking to exchange ideas. I recommend developing a comprehensive manual (student and faculty versions) to aid and ease implementation. Overall I am extremely satisfied with the GEP experience for both faculty and students.
Ken Saville, Albion College, MI: Absolutely! The availability of a wide range of projects and the supporting infrastructure allow the material to be taught at a variety of levels. Belonging to a larger research partnership is also gratifying for me and for my students. The ability to pull together lots of data to submit for publications is dependent on the overall structure. It would be difficult, if not impossible, for me to generate and analyze sufficient genomics data for publication.
Stephanie Schroeder, Webster University, MO: I agree that the central support is essential. It was important to both my students and to me to have the incredible help and advice of the GEP support team.
Karim Sharif, LaGuardia Community College, NY: The great resources of training handouts, exercises and videos are instrumental in training students for GEP research. Moreover, the central support system's exceptionally prompt response via e-mail to any troubleshooting inquiries during the research minimizes any time loss associated with learning by trial and error or waiting for the response. Without the central support this research would not be possible.
Mary Shaw, New Mexico Highlands University, NM:

I agree with many of the others that central support is essential, especially for small schools. We do not have the numbers needed to show statistically significant results of pedagogical changes, or the background to know how to do all of the things that a team can do.
Gary Skuse, Rochester Institute of Technology, NY: Central support is not necessary for my implementation because we use GEP materials in a formal course that follows more foundational courses in bioinformatics and genomics. Generally, the students in our course are relatively sophisticated with regard to bioinformatics. During the academic term support is provided by the instructor and teaching assistants who together provide whatever enrolled students need.
Mary A. Smith, North Carolina A & T State University, NC: The GEP offers an excellent opportunity for students to conduct cutting-edge research in genomics. The centralized GEP support is essential because the genomics and bioinformatics fields are forever evolving as new tools are generated, databases are added to and updated, and new information is publicized at an ever-increasing pace. The centralized support reduces the challenges of sustaining the quality of the course without professional help. It is an excellent model for sustaining professional development in teaching and learning and for exposing students at all institutions to the same level of rigor and cutting-edge science.
Sheryl T. Smith, Arcadia University, PA: I feel that having a central support system is critical to the success of our Bioinformatics course.
Eric Spana, Duke University, NC: Centralized support is essential for the success of the semester. When something goes wrong, there are incredibly helpful folks to lend a hand. It also made starting in the program extremely easy, because the activation barrier was so low.
Mary Spratt, William Woods University, MO: While faculty at some larger and more sophisticated institutions could no doubt carry on without our centralized life line at Wash U., it is absolutely critical at my institution, and probably at most smaller schools. Knowing that the staff and their supporters are there to answer our questions (as well as to get us together for catch-up every year) is essential. I hope the system keeps on being energized for a long time yet!
Aparna Sreenivasan, Cal State University – Monterey Bay, CA: Yes, for me (a person trained in molecular biology in 1995-2000) a central support system is absolutely necessary. I rely heavily on the training and support of GEP. The opportunity for my students to be authors on the publications drives many of them to work at a higher level. Also, through GEP I have met many other faculty who are implementing similar courses at their institutions, and we work together on grant proposals, present GEP related research at scientific meetings and generally support each other. Without this support system, I would not be as successful with my own scholarship in this area. It is also exciting to be working on a cutting edge educational project with faculty from across the country - motivational for the professor AND for the students. In addition, the network provides a structure that I can discuss with my colleagues at my institution, and currently is helping me acquire buy-in at my own institution with regard to the importance of teaching and emphasizing genomics curriculum.
Joyce Stamm, University of Evansville, IN: The central support system is absolutely critical. I could teach Genomics without the GEP, but I couldn't teach it in the same way - by engaging my students in a meaningful research project with prospects for publication. I simply don't have the time or expertise to develop the projects or resources that the GEP provides. Another important aspect of the centralized system is that it provides community - discussing my successes and challenges with like-minded colleagues has been helpful and motivating.
Jeff Thompson, Denison University, OH:

A centralized system to coordinate these projects is absolutely essential. While I have been able to develop some small-scale projects in genomics to implement in my course, they do not have the same impact as a project that is part of a larger, coordinated effort.
Matthew Wawersik, College of William and Mary, VA: Absolutely. First and foremost, the central support provides a unifying research question that we can work together to answer. The central support system also gives us the capacity to efficiently share curricula, solve research problems, and come together as a community of diverse scientists.
Michael Wolyniak, Hampden-Sydney College, VA: Absolutely. As a small institution with limited research resources, we rely on initiatives like the GEP to provide the centralized "big picture" question to which our students can contribute. We can, of course, devise our own more local projects, but the scale of the GEP's research and the opportunity for collaboration with students from other institutions are large motivating factors for our students to become involved.
Jim Youngblom, California State University – Stanislaus, CA: I would have a very difficult time sustaining the idea of involving undergraduate students in original research in gene annotation without the central support system. The availability of the projects, the annotation tools, technical support, and the project management system are all critical to my success at engaging students in genomics research.
Leming Zhou, University of Pittsburgh, PA: Since I was trained as a computer scientist and do comparative genomics research, I do not need much technical support related to computer systems or software. However, I do need guidance on biologically meaningful projects and gaining access to first-hand genomic data. Therefore, a centralized support from a leading biologist is critical for me to continue this project.

Supplement S5 Responses to incentives

"What do you perceive as the most significant incentive for sustaining your efforts to teach genomics by engaging students in research?"

Symbol	Code
1	Participation in real research
2	Increases student learning
3	Contribution to field
4	Scientific community
5	Keeping up with the field
6	Prepare students for the future
7	Feasibility
8	Increases student motivation
9	Valued by institution

Comment
Consuelo Alvarez, Longwood University, VA: Faculty are interested in joining this type of research project, and thus GEP, as it provides training for them as well as student TAs in the new and interesting area of bioinformatics. We, as educators, need to be up-to-date in this rapidly growing field. Sharing this opportunity with our students increases their marketability for jobs and boosts their success in their graduate programs.
Daron Barnard, Worcester State University, MA: First and foremost the most significant incentive is the ability to provide my students with research opportunities. The GEP provides a project that is flexible and inexpensive to implement - it provides my students with research opportunities that otherwise would not be accessible, and the possibility for student publication. It also can be implemented in a way that reaches more students than a typical research project. I also appreciate that my continued participation keeps me engaged in the field and engaged in a community of researchers brought together by the GEP. This community is an important factor in my continued participation. Finally, my institution values my participation in the project, both in getting students into research and for the student presentations that come out of it, as well as our participation in science education publications.
Chris Bazinet, St John's University, NY: I see this as a win-win for my students and me: Working on a research problem reinforces the students' understanding of basic concepts in genetics and molecular biology more deeply than "the problems at the end of the chapter" ever seems to. They are working on real problems, with real and unique solutions that also constitute small but genuine contributions to the progress of science. For faculty at teaching-intensive institutions, this is a great opportunity to acquire tools that may inspire and help forge new directions for their own research. Knowing that significant resources of major scientific institutions (WUSTL and HHMI) are invested in the project gives additional assurance that the investment of my time in this effort is more likely to result in a lasting educational and research resource that will keep up with developments in the field. The opportunity to share in publications resulting from the collaboration provides substantial icing on the cake
Dale Beach, Longwood University,VA:

There are two primary incentives: first is the incentive to provide access to "Name-Brand" research opportunities. The research opportunity is novel for many of our students, and begins to break the mold of learning for the test. Students working on the genomics project are directed to try to explore the process of understanding and interpreting data instead of memorizing results. The partnership with WUSTL lends an air of importance, or at least the greater weight of a well-known institution as compared to a small, central Virginia university. Second, working with the materials, data, and support of the GEP program provides an active learning component to Genetics and Molecular Biology courses that extends beyond "canned" labs and classroom assignments. For any course, even light exposure to the genomic research provides the "real world" impact of the field.
James E.J. Bedard, University of the Fraser Valley, BC, CA: The most significant incentive for me is seeing my students engaged in their work throughout the class, and showing their enthusiasm for the material.
April Bednarski, Lindenwood University, MO: My main incentive has been to connect to a larger community of scientists, learn new research skills, and pass along opportunities to my students through independent research projects, research-based labs, and opportunities to publish. My institution regards my involvement in GEP as contributing to my career advancement through continuing professional scholarship and by being able to offer an innovative lab for students.
John Braverman, St. Joseph's University, PA: The most significant incentive for me is that research cultivates intellectual growth in students. Not only do they learn about the eukaryotic genome (at a level and appreciation far deeper than from a mere lecture), but they also grow in problem-solving ability. Along these lines, they seem motivated by the chance to work on a problem and happy when they succeed.
Martin Burg, Grand Valley State University, MI:. One of the most significant incentives for sustaining this effort has been the ability to have more students experience a research project than normally would be able to have that experience, resulting in the possibility of publications for them. As many of our students are in a premedical curriculum, the changes that are likely to emphasize genomics will allow this effort to be sustained. It does also keep me connected to a larger group of like-minded educators and scientists who want to have more students experience this type of collaborative research project; without the GEP, none of this could accomplished.
Vidya Chandrasekaran, Saint Mary's College of CA: The biggest incentive is for me and my students to be involved in high quality research with large institutions such as Wash Univ. and the potential for publications from this research. The other main incentive for me is to learn new tools and ideas in Genomics and Bioinformatics. This allows me to be a better teacher for my students.
Hui-Min Chung, University of West Florida, FL: The biggest incentive for me is to use research projects to enhance students' capacities to achieve better reasoning, better organization and better ability to deal with large set of data. These skills are extremely important regardless of the future professional tracks that the students are taking.
Randall J. DeJong, Calvin College, MI: The most significant incentive is to give a large number of students a meaningful research opportunity, one that produces new knowledge, demonstrates the collaborative nature of science, and may lead to publications. Moreover, it's in an area (genomics) that many of them will find intersected with their future work in graduate school or elsewhere, even if they don't go into genomics specifically.
Justin R. DiAngelo, Hofstra University, NY: The most significant incentive for teaching genomics by engaging students in research is the

opportunity to produce new knowledge that will result in publications in the primary scientific and education literature, a benefit for both the students and myself.
Chunguang Du, Montclair State University, NJ: Teaching genomics by engaging students in research is the key outreach component for my NSF project. I will keep this practice as long as I apply for grants from NSF.
David Dunbar, Cabrini Collage, PA: The most significant incentive is the opportunity to merge and intersect research and pedagogy. Plus, being part of this program allows me to stay up-to-date on cutting edge genetics/genomics research in a eukaryotic system.
Todd Eckdahl, Missouri Western State University, MO: The most important reason I continue to use the GEP approach in my course is that it has a dramatic impact on the education of my undergraduate students. By engaging in original genomics research, my students are able to learn many of the lessons associated with independent research. They learn how to apply knowledge, how to develop and test hypotheses, how to evaluate contradictory lines of evidence, and how to use critical thinking in science. They gain valuable skills in teamwork, computer analysis, and scientific communication. In addition to these educational benefits, my students get the chance to engage in authentic research as they become partners in a nationally distributed research project that is contributing to the advancement of genomics.
Sarah Elgin, Washington University in St. Louis, MO: It is exciting to see what the students can accomplish, and what we are learning about genes and genomes from their efforts. And it allows me to work with a great group of colleagues, faculty who are dedicated to bringing their students into the scientific community.
Julie Emerson, Amherst College, MA: I believe that the most significant incentive for teaching genomics by engaging students in the research mission of the GEP is that it allows for a larger number of students to join a research enterprise than can do so by working in an individual faculty member's lab. The versatility of the GEP curriculum also enables students to engage in original research earlier in their college careers, which is often a deciding factor in students electing to pursue a major in the sciences. Finally, students are intrigued by the collaborative nature of the GEP, and they enjoy contributing to a project that is also being worked on by students from other colleges and universities across the country.
Amy Frary, Mount Holyoke College, MA: Providing undergraduate students with a meaningful and original research experience which also reinforces concepts taught in the classroom is the most significant incentive.
Don Frohlich, University of St. Thomas, TX: GEP is clearly the best and most efficient means of introducing students to real data at a school without the resources to generate those data. Often our efforts at research concentrate on laboratory techniques and data collection. With the limited scope of our projects, we have precious little time or opportunity to collect and analyze complex data. GEP very effectively bridges the gap between laboratory and data evaluation within a defined project.
Anya Goodman, Cal Poly State University – San Luis Obispo, CA: Student enthusiasm and success keep me motivated to continue teaching GEP curriculum. Student attitudes toward learning change when students learn by engaging in research. Without the research component, students often see learning as something that may be useful someday, but at the time is only needed to pass the test. Research goals give meaning and immediate application to the knowledge and skills students acquire. That's a powerful motivator for students to work hard to succeed and for me to continue supporting them.
Yuying Gosser, The Grove School of Engineering, The City College of New York, CUNY, NY My hope is to offer a computer-based, research-oriented concise course in genomics and

bioinformatics to all engineering students as a required course, just like the one-semester course of General Chemistry, which is a required course for all engineering majors. Engineering students (except BME) normally have no time to take the one-year introductory courses Bio-101 and Bio-102 which are the pre-requisite for all advanced Biology courses, and therefore the broad biology field becomes a "foreign" or "forbidden" territory for them. This is not acceptable for modern engineering education. GEP has provided strong support for me to pursue my goal. The Central Dogma of molecular biology forms a framework for students to understand the genome and related biology systems. The research-oriented projects, like gene annotation and protein structure-function analysis, train students to use the primary bioinformatics database and online tools, and set a stage for them to learn by themselves and further explore the world of biology. We believe this will have a profound impact on engineering students' view of the world and their thinking.
Shubha Govind, Biology Dept., The City College of New York, CUNY, NY: Keeping students abreast of and participating in the latest research using unconventional tools for the biologist is a major incentive. The GEP curriculum provides a powerful alternative to traditional lab-based learning methods.
Adam Haberman, Oberlin College, OH: The ability to give students meaningful hands-on experiences to support their understanding of genome sequencing and analysis is the major incentive.
Amy T. Hark, Muhlenberg College, PA: The opportunity to engage students in problem solving that adds to new scientific knowledge (i.e. is publishable) in a cost-effective manner is a primary incentive for me.
Charles Hauser, St. Edward's University, TX: The incentives for me are the value of (1) engaging students in high quality collaborative genomics-based research with the expectation that their combined work is of sufficient quality for peer-reviewed publication; (2) working with the GEP community, with a focus on building curricula in genomics and bioinformatics; and (3) engaging students in open-ended experiential learning experiences, which is of growing importance at my university, a Hispanic-serving institution.
Arlene J. Hoogewerf, Calvin College, MI: The most significant incentive is that students have the opportunity to engage in real-world research that allows them first, to discern whether research or graduate school is a good option for them; and second, for graduate-school-bound students, to have the research experience and/or publications that will enhance their applications for acceptance intro graduate programs.
Diana Johnson, George Washington University, Washington DC: The most significant incentive is the ability to have students work independently on a research project. I find it very rewarding to have the students actually work at the nitty-gritty level and really apply their knowledge and expand it.
Christopher J. Jones, Moravian College, PA: Genomics is an area that I personally am interested in and enjoy, which makes it more pleasant, and it's increasingly relevant to students' lives both personally and professionally. The GEP's approach engages students with a constructive, hands-on experience that is flexible enough to allow me to focus on those aspects of genomics that I feel are most valuable for students; the project affords them the opportunity to contribute directly to the larger scientific enterprise, which is something they often don't see in their other coursework.
Lisa Kadlec, Wilkes University, PA: There are multiple incentives to sustained teaching of genomics through involvement in GEP, and it is difficult to select one as most significant. I think the main things are 1) being able to engage students in a real, current research project while teaching them about an area that many of them would otherwise not be exposed to (or at least not in such a hands-on way), and 2)

the collaboration with other GEP faculty and the benefits to me in terms of increasing my own knowledge and facility in the area of genomics.
Marian Kaehler, Luther College, IA: I have only been able to provide a two-lab exercise in annotation in my Genetics course; it is difficult to do this well, but I am primarily motivated by the awareness of the depth of insight students can gain into both fine gene structure and evolution. Annotation is a window into point, karyotypic, and genomic evolution.
S. Catherine Silver Key, North Carolina Central University, NC: Honestly, the main incentive for sustaining my teaching of genomics research is the feeling of ownership and teamwork that the GEP Consortium provides. The ideas we generate to engage students and measure how our teaching activities affect their career choices energizes me. I have always been fascinated with unlocking the mysteries held in the double helix and the GEP Consortium provides me the training wheels to keep up with the fast-paced world of genomics.
Nighat P. Kokan, Cardinal Stritch University, WI: The opportunity to engage our students in a "real" research project that they can carry out as part of a course has been great. We are a "teaching heavy" institution, which does not allow for any research time outside the classroom. Additionally the "no cost" annotation projects (in terms of consumables and reagents) are also important as we do not have a research budget. Being able to expand my research experience and scholarship activities has been an added bonus. The same can be said for our students.
Olga Ruiz Kopp, Utah Valley State College, UT: The most significant incentive is the excitement that students show when having the opportunity to participate in research and be part of a group producing data that can be used by the community at large. Students change their view of science when given the opportunity to have hands-on learning. In addition, as a faculty member, having the opportunity to interact with scientists in other fields and learn how to apply this knowledge to other organisms is vital for my career growth. GEP is a great opportunity for any faculty member at any school, including primarily undergraduate institutions.
Gary Kuleck, University of Detroit Mercy, MI: There are two drivers for me to sustain the GEP experience. First, and foremost, I have seen the 'leaps' in student grasp of and interest in bioinformatics and genomics achieved by providing authentic research experiences. Most students respond very positively to this opportunity. Second, I have kept abreast of advances in bioinformatics by being engaged in this extended national research project. It has helped to advance my career with enhanced scholarly publications and brought me in contact with colleagues nationally who are involved with undergraduate teaching and research.
Christy MacKinnon, University of the Incarnate Word, TX: The faculty scholarship performance standards at my school awards merit increases for implementing authentic research in an undergraduate class. Without this university-wide reward system, I probably would invest my scholarship time in something different that would result in faculty merit pay.
Juan C. Martínez-Cruzado, University of Puerto Rico at Mayagüez, PR: The GEP project is a way to keep myself up to date in the fast-evolving field of genomics. Just as important, our mission is to educate, and training in genomics has become absolutely necessary for any undergraduate who may be interested in pursuing graduate studies in genetics.
Gerard McNeil, York College, CUNY, NY: My main incentive to continuing this effort is the benefit that I have seen the students gain from this experience. It teaches them important content about gene structure, genomics, and bioinformatics in addition to how to solve a real scientific problem using critical thinking skills.

Former students have told me how instrumental this experience was in preparing them for later experiences in either jobs, graduate, or medical school. Involvement in this partnership allows me to expose many more students to a real research experience.
Stephanie Mel, University of California, San Diego, CA: There are multiple incentives for continued involvement in a project such as this, but one of the main ones is to give students the opportunity to be involved in real research and to generate novel data in a classroom setting. The students were tremendously excited about being able to do this. The small interactive class was another highlight for students and teacher alike, as most classes at this large undergraduate institution don't offer this level of student/faculty interaction.
Alexis Nagengast, Widener University, PA: I think my biggest incentive is seeing how much the students learn from their hands on experience with annotation. My research is in the field of alternative splicing in Drosophila and when students annotate a gene for the GEP project, they come away with a better sense of understanding of splicing and gene structure than I could ever provide by just talking about it or having students read papers on it. Plus I get to stay current with advances in genomics by attending the GEP Workshops and this helps me in my research as well.
Paul Overvoorde, Macalester College, MN: Preparing students for the future is the biggest incentive. A glance through national reports calling for biology education reform reveals the need for our students to efficiently process and effectively analyze genomic data. In addition, research-based questions pique student interest and stimulate self-directed learning. Finally, the GEP community provides encouragement and stimulates my interest in engaging students with research questions.
Don Paetkau, St. Mary's College, IN: The chance for my students to take an active/engaging Genomics course. I could not teach this course in this interactive way without the support, discussions and help from the consortium. As the AMA has said that every student entering the health field should have a Genomics course, it is imperative to teach the material. The biggest incentive is that I get to teach what can be a difficult and detailed subject in a hands-on, real research venue. The professional interactions are also a huge incentive when teaching at a college where few colleagues are thinking about genomics.
Susan Parrish, McDaniel College, MD: I find that student gains are greater when they actively engage in research, and I would like all of my laboratory classes to be research-based. From the annotation project, the students gain a better understanding of gene structure than can be acquired from lecture material. They also learn to formulate a hypothesis and use multiple lines of evidence to support or negate this hypothesis. They take pride in their work and in the knowledge that they are making a real contribution to science.
Mary Preuss, Webster University, MO: The research venue allows students to take an active role in their learning experience. Seeing them grow as scientists is the greatest incentive for me to teach this material. But also, this forum provides an opportunity for me to grow professionally and network with other scientists from different fields of expertise.
Laura K. Reed, University of Alabama-Tuscaloosa, AL: For me, the pride of ownership the students have in knowing the work they are doing is original, useful, and potentially publishable, is extremely gratifying. Students are much more willing to push through the frustration of the research project if they know they are the person best suited to find the "correct" answer and their instructor does not already know the answer. Also, they are extra motivated if they know they will receive some recognition beyond a letter grade for their efforts.

E. Gloria Regisford, Prairie View A&M University, TX: My incentive is the joy of involving a large number of students in research. The students in my classes become so engaged in science research, with frustration and then elation upon finding a solution, that I, myself, get excited in observing their growth and increased maturity as they learn new concepts.
Dennis Revie, California Lutheran University, CA: Originally, the incentive was participating in a genomics project. I now have two incentives. First, I see that the incorporation of the finishing and annotation projects into my classes has given the students not only a feeling for research, but also an experience of dealing with lots of imperfect data. This lets them see a part of science that you don't normally see as an undergraduate. Second, I enjoy the other members of GEP. I look forward to seeing everybody each year at the Wash U GEP Alumni Workshops.
Srebrenka Robic, Agnes Scott College, GA: GEP provides me with the framework to engage undergraduate students in exciting, original research without a high cost associated with it. This is especially important at my small women's liberal arts college with very minimal funds available for student and faculty laboratory research.
Jennifer A. Roecklein-Canfield, Simmons College, MA: The most important incentive is the way in which the GEP projects expand the repertoire of authentic research projects available for students. Additionally, the opportunities GEP provides for the introduction of bioinformatics tools into curriculums that may not have stand-alone courses in bioinformatics in their programs is important.
Anne Rosenwald, Georgetown University, Washington DC: The most significant incentive from projects like GEP for me is being able to bring authentic research projects to large numbers of students using current tools.
Michael R. Rubin, University of Puerto Rico at Cayey, PR: A significant incentive for sustaining efforts such as those pioneered by the GEP is the belief and conviction that engaging students in original research experiences is an effective and exciting way to enhance student learning. Current thinking and research in biology education reaffirms the importance and effectiveness of active student learning as provided by research endeavors. At UPR-Cayey, students are required to participate in research experiences, creative endeavors, or community service. Research experiences are also important for faculty, and students can help advance faculty research efforts. Since accreditation agencies also recognize the importance of activities such as research that promote active student learning, administrative support may also be available as an incentive.
Ken Saville, Albion College, MI: The best incentive is the ability to offer research opportunities to my students. There is a continual and increasing demand for research opportunities for students and the ability to provide genomics projects in the context of a class and for directed studies is an excellent solution. Also, the ability to co-author various publications is a strong incentive.
Stephanie Schroeder, Webster University, MO: The GEP has allowed me and my students to participate in genomics research. It has also allowed me to interact with interested colleagues from around the country. The GEP community has been a valuable resource.
Karim Sharif, LaGuardia Community College, NY: My institution places a huge emphasis on student mentoring and the scholarship of teaching and learning by the faculty. Engaging students in GEP research projects afforded the opportunity to mentor students in original research projects in a very cost-effective and time-efficient manner, and to enhance my scholarship of teaching and learning at the same time. Publication in peer-reviewed journals is an invaluable advantage and thus incentive for

sustaining the GEP research. Moreover, engaging students in GEP research projects facilitated effective teaching of concepts in genomics to biology students, who may otherwise not have had an adequate learning experience in this area, because it is taught only as part of the Fundamentals of Biology course. In fact, GEP research has expanded the horizons, encouraging students from other disciplines to engage in genomic research and gain an understanding of eukaryotic gene structure and comparative genomics.
Mary Shaw, New Mexico Highlands University, NM: For me, there are several ways that the GEP provides incentives. I am interested in genomics but do not have a strong background in this area, and I am at a small school where nobody else does either. Involvement with GEP allows me to learn about and participate in this topic. I also think that it is important for our students to learn the basics; with help from the GEP, I can help them learn genomics in an investigative manner. Students have been hired at least partly because they had this experience. I am also interested in science education, and the GEP provides a venue to engage with other faculty members who are looking at ways to improve our efforts. The fact that we are publishing both in the science education and in the general science literature is also extremely important to me. The price of doing genomics research is right for a small school too!
Gary Skuse, Rochester Institute of Technology, NY: Our students respond to their involvement in research with enthusiasm and verve. Until recently they were only given opportunities to engage in research outside of the traditional classroom, while working in faculty laboratories. The course I offer as part of the GEP was one of the first in our department that allowed students to exercise their creativity in the discovery process in class. Since then we have incorporated research into many courses, including our freshman biology sequence. In every case students report a sense of satisfaction in the knowledge that they are able to apply their learning and creativity to address real scientific questions, despite the inherent frustrations they encounter while doing novel research. This response is sufficient incentive to continue teaching genomics through the sorts of research experiences offered in my GEP-supported course.
Mary Smith, North Carolina A&T State University, NC: The most significant incentive for sustaining my efforts to teach genomics by engaging students in research is the outcome of the process. Training students in genomics research is critical for producing the next generation of scientists who will be needed to explore and use the vast amount of genomic information that is constantly emerging, to solve biological problems. The GEP research project fosters deeper learning through cooperative engagement and critical thinking through an unsolved problem. This instructional approach is very challenging but the success of the students in the end is very rewarding. The GEP research project aligns well with our curriculum efforts to increase research experiences for students inside and outside the classroom. The value added by the GEP project is the low cost associated with incorporating genomics research into a course. The structure and resources provided by the GEP is critical to the success of implementing the annotation projects nationwide and at my institution.
Sheryl T. Smith, Arcadia University, PA: Teaching through engaging students in research is absolutely my preferred method of instruction. I have had the pleasure of mentoring many students through research projects in my laboratory. Time and again students remark that applying their knowledge in the context of a research project allows for a deeper understanding of concepts and techniques they felt they had already mastered in courses like biochemistry, molecular biology, genetics, etc. Similarly, students may feel “comfortable” with the concepts in genomics, but truly gain deeper insight into genome structure and evolution by engaging in genomics research. Although many science courses have a lab component that serves to reinforce concepts learned in the classroom,

teaching through research is preferable, in my opinion, because it gives students the opportunity to develop critical thinking skills, collaborate with peers and to develop communication skills in order to impart findings. For all of these reasons, I will continue to use this approach to genomics education.
Eric Spana, Duke University, NC: I find (still) the discovery process to be exhilarating and I hope that rubs off. Following procedures in the classroom to yield a result is so incredibly boring for me as an instructor. This type of course makes every day interesting and exciting and makes you happy to come to work.
Mary Spratt, William Woods University, MO: A big incentive for me is to be able to involve entire classes in novel research on a very low budget. My other research project is costly, time consuming and can only accommodate a few students at a time. The parallel research experience is a great design, both for students to see that others in distant places are working on similar projects, but also for faculty at small institutions like mine, where one may be the only person in that field; the collaboration with other faculty is great.
Aparna Sreenivasan ,Cal State University-Monterey Bay, CA: A huge incentive for me is to be able to engage more of our students in meaningful research experiences. The students are extremely excited about these projects, so much so that they ask for more projects beyond what we do in the classroom, want to use these projects as senior theses, and are requesting to present these projects at scientific meetings. When students "learn by doing" and are exposed to building a research question, charting new territory, and being a part of a team of scientists working toward a common goal, they are truly engaged in a way that I do not see in my introductory genetics course. A course that incorporates research in the classroom, especially genomics, increases students' self esteem, and draws more of them into the intricacies of the world of the research scientist.
Joyce Stamm, University of Evansville, IN: This course is built on what I think is the most enjoyable aspect of my job - working one-on-one with students to solve problems, with the bonus that I don't necessarily know what the answers are. It is so energizing (although more than a little scary) to teach a course where I can't predict what's going to happen at the beginning of the semester.
Jeff Thompson, Denison University, OH: The primary incentive for me is the payoff I observe in my students who engage in these projects. Knowing that this is "real research", the students put in the extra effort to learn about the project and to ensure that their work is high quality. It opens their eyes to a side of biology that they likely did not know existed, and for at least some of them, it encourages them to consider alternate career paths.
Matthew Wawersik, College of William and Mary, VA: The most significant incentive for sustaining my efforts for teaching genomics by engaging students in research is that I get to teach a lab course that engages me in research as well. Furthermore, this research is somewhat outside my normal research area so it stretches my abilities, teaches me new concepts, and allows me to further my knowledge of biology in general. The opportunity to engage students outside of my research lab in primary research and interact with a diverse and stimulating community of scientists that produces publishable work as a group is also quite beneficial.
Michael Wolyniak, Hampden-Sydney College, VA: Our experience has shown that students get most excited about genomics when we engage them in authentic experiences to present the topic. By providing students with genomics classroom and laboratory projects that contribute to answering real scientific questions, with the strength of a broad group of peer scientists, our students come away with a genuine

passion for research that leads them into ideas for their careers that they did not consider before.
Jim Youngblom, California State University – Stanislaus, CA: The incentive is two-fold. I am getting feedback (from personal communication and from exams) that students are grasping the class content in a way that is superior to the way material is received from lectures. In addition, I find that I can require more of myself and of my students with each new group of GEP students. Continued involvement in GEP forces me to stay abreast of the latest developments in the rapidly changing field of genomics, which benefits my students and enriches me professionally as a molecular biologist.
Leming Zhou, University of Pittsburgh, PA: The primary incentive for me is that this is a good way to introduce genomics research to undergraduate and graduate students, and I can see that those students become more active learners and better problem solvers.

Supplement S6 Schools Represented in the GEP, 2006-2012

Schools joining the GEP between June 2006 and January 2012 are listed. If more than one faculty member from that school joined GEP, the number is given in parentheses following the school name.

Institution	Month and Year Joined
Adams State College	January 2010
Agnes Scott College	June 2011
Albion College	June 2007
Amherst College	June 2009
Arcadia University (2)	August 2009, June 2011
Austin College	June 2007
Bronx Community College, City University of New York	June 2011
California Polytechnic State U – San Luis Obispo	June 2006
Cabrini College	June 2011
California Lutheran University	June 2006
California State University- Northridge	June 2006
Calvin College (2)	August 2009, August 2011
Cardinal Stritch University	June 2008
City College of the City University of New York	June 2008
College of Charleston	June 2009
College of William and Mary	June 2008
California State University - San Marcos	June 2011
California State University- Monterey Bay	June 2011
California State University-Stanislaus	June 2007
California State University-San Bernardino	June 2009
Denison University	June 2007
Duke University	June 2008
Emmanuel College	August 2009
Galen College of Nursing	June 2006
George Washington University	June 2008
Georgetown College	June 2009
Georgetown University	June 2007
Grand Valley State University (3)	June 2009, June 2010, June 2011
Hampden-Sydney College	June 2011
Harding University	August 2009
Hartwick College	June 2008

Hofstra University	June 2010
Jackson State University	June 2007
Johnson C Smith University	June 2008
LaGuardia Community College	January 2012
Lindenwood University	June 2010
Longwood University	June 2007
Loyola Marymount University	June 2006
Luther College	August 2008
Macalester College (2)	June 2006, June 2008
McDaniel College	June 2008
Missouri State University	June 2006
Missouri Western State University (2)	June 2006
Montclair State University	June 2006
Moravian College	June 2006
Mount Holyoke College	June 2011
Mount Saint Mary College (2)	June 2010
Mount San Jacinto College	June 2010
Muhlenberg College	June 2009
New Mexico Highlands University	June 2006
North Carolina A&T State University	June 2007
North Carolina Central University	June 2009
Oakland University	June 2010
Oberlin College	January 2012
Pomona College	June 2008
Prairie View A&M University	June 2007
Purdue University	January 2012
Rochester Institute of Technology	June 2006
Saint Joseph's University	June 2011
Saint Mary's College	June 2009
San Francisco State University	June 2007
Simmons College (2)	January 2010, June 2010
St. Edward's University	June 2006
St. Mary's College-California	June 2008
Texas Wesleyan University	August 2007
University of Nebraska- Lincoln	August 2008
University of the Virgin Islands	June 2008
Universidad de Puerto Rico en Humacao	June 2006
University of Alabama - Tuscaloosa	August 2011
University of Alabama at Birmingham	June 2011
University of California San Diego	August 2009
University of Evansville	June 2007

University of Pittsburgh	August 2009
University of Puerto Rico at Cayey (2)	June 2011, January 2012
University of Puerto Rico at Mayaguez	June 2009
University of St Thomas	June 2008
University of Tennessee - Martin	June 2011
University of the Incarnate Word (2)	June 2010, June 2010
University of West Florida	June 2007
Utah Valley University	June 2006
Washington and Lee University	June 2009
Washington University in St Louis	June 2006
Webster University (2)	June 2006, June 2010
Widener University (2)	June 2007, August 2007
Wilkes University	June 2009
William Woods University	August 2007
Wolford College	June 2008
Worcester State College	June 2007
York College, City University of New York	June 2007

Supplement S7 Table of faculty ratings

Table of items that may serve as incentives or barriers to implementing and sustaining GEP activities (anonymous survey). Respondents rated each item twice; first, as important, on a scale of 1 (marginal importance) to 5 (very important); second, as present on the campus when the respondent attempted to implement the genomics activities, on a scale of 1 (absent) to 5 (present in abundance). Items are ranked by importance. A graphical representation is given in Fig. 1A.

Items	Mean importance	Mean presence	Difference	Importance SD	Difference in SD units
Acceptance of research in curriculum	4.68	3.92	0.76	0.58	1.31
Acceptance of genomics in curriculum	4.42	3.21	1.21	0.88	1.38
Expertise in genome-related topics	4.4	3.41	0.99	0.66	1.5
General molecular biology expertise	4.39	4.27	0.12	0.8	0.15
Availability of computing facilities	4.37	3.62	0.75	0.79	0.95
A reasonable teaching load	4.24	3.17	1.07	1.2	0.89
Familiarity with bioinformatic tools	4.22	3.57	0.65	0.7	0.93
Quality of computer resources	4.18	3.29	0.89	1	0.89
Experience teaching lab courses	4.13	4.1	0.03	1	0.03
Overall experience as a research mentor	4.07	4.17	-0.1	1	-0.1
Support from department chair	4.05	3.81	0.24	1	0.24
Appreciation from undergraduates	3.98	3.76	0.22	0.9	0.24
Availability of teaching assistants	3.96	2.76	1.2	1.1	1.09
Quality of IT support	3.73	2.91	0.82	1.1	0.75
Support from faculty colleagues	3.73	3.21	0.52	1	0.52
Your control over the calendar	3.7	3.4	0.3	1.3	0.23
Experience as a mentor to men and women	3.64	4.04	-0.4	1.3	-0.31
Your control over weekly schedule	3.6	3.52	0.08	1.4	0.06
Adequacy of programming skills	3.58	2.89	0.69	0.9	0.77
Experience as a mentor to diverse students	3.53	3.76	-0.23	1.3	-0.18
Positive publicity	3.52	3.12	0.4	1.3	0.31
Support from staff	3.36	2.71	0.65	1.3	0.5
Alignment between GEP and research interests	3.21	3.01	0.2	1.2	0.17
Experience with Drosophila	2.94	2.89	0.05	1.4	0.04
Curriculum oversight	2.59	2.57	0.02	1.2	0.02

Supplement S8 Factor loading for barrier survey items

The 25 items that were ranked in Q. 21 of the faculty survey were analyzed using exploratory factor analysis. The best model had five factors, with 22 of the 25 items strongly loading on to one of the factors. The number next to each entry indicates the position of the item in the survey. Items #17, #24 and #25 (appreciation from undergraduates, positive publicity, and experience with Drosophila, respectively) are missing because they are not strongly associated with any factor.

Barriers subscales		**Factor loading**
Teaching/mentoring experience		
15	Your expertise generally in molecular biology	.626
18	Your experience as a research mentor to students of diverse races/ ethnicities	.888
19	Your experience as a research mentor to both female and male students	.826
20	Your overall experience as a research mentor	.877
21	Your experience teaching laboratory courses	.740
Familiarity with genomics		
1	Acceptance of genomics in biology curriculum	.450
14	Your expertise in genome-related topics	.734
16	The alignment between GEP and your research interests	.533
22	Your familiarity with bioinformatics tools	.841
23	Adequacy of your programming or other computer savvy skills	.679
Administrative support		
2	Acceptance of research within the curriculum	.379
3	Support from department chair	.719
4	Support from faculty colleagues	.826
5	Support from staff	.426
6	Your control over when to offer the course on the calendar	.673
7	Your control over the place of the course on the weekly schedule	.628
Computing support		
10	The oversight by the college/ university curriculum committee	.778
11	The quality of IT support	.601
12	The availability of computing facilities	.726
13	The quality of computer resources	.718
Teaching support		
8	The availability of TAs	.475
9	A reasonable teaching load	.712