2010

Spring 2010: Research Opportunity for Undergraduates

Mark Rast
University of Colorado, Boulder, Mark.Rast@Colorado.EDU

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Spring 2010: Research Opportunity for Undergraduates

Mark Rast

11 May 2010

“After this experience I believe that any student interested in research should be given the opportunity regardless of GPA or career path. The very practice of exploring a question and using various resources and techniques to answer that question is a fundamental skill that can not [sic] be taught in a class room [sic]. Only through experience can students learn what research really is.” (Student participant in anonymous exit survey)

The goal of this effort was to engage a broader range of undergraduates (beyond those with the highest grades) in research, and to document what strategies work and where the difficulties lie in providing that broader population a meaningful undergraduate research experience. This then may lead to a more formalized undergrad research program in the department (if we decide we want to go that way), or more informally to some shared insights.

Here I document as completely as possible what I have learned. Many of these things are well known to those with more experience, but I made no attempt to separate my naiveté from the presentation of the results. Those with limited time may wish to initially focus only on those passages marked in cyan italics to determine whether there is anything worthy of their closer attention.

Eighteen students from APS participated in this one semester research opportunity. Each of them was individually mentored, one-on-one, by teaching and research faculty and postdoctoral researchers rostered in CASA, JILA, and LASP. They engaged in paid research for up to 20 hours per week (supported by resources from the Provost’s Office) while simultaneously being enrolled as full time students. They were additionally enrolled in a one unit independent study class which met in two groups, each once per week, to discuss strategies, techniques, tools, and science in the context of their research. All but two of the students delivered 25-minute presentations on their research during these sessions. Of the 18 students enrolled in the program, 1 graduated at the end of the semester, 14 have elected to continue working with their mentors into the summer (until the provost resources have expired), and 6 (so far) have been offered longer term continuation of their projects by their individual mentors. This later number will be updated at the end of this document by summer’s end, when it is clearer whether individual projects will continue.
Summary Points:

- Undergraduates of all academic skill levels within our department have a passionate desire for research experience. Many have GPAs well below what is needed to be readily considered for admission into graduate programs.

- Along with this eagerness comes a dramatic underestimation of the difficulty of scientific research and a consequent inflated sense of their readiness and potential contributions.

- A primary benefit of a broad undergraduate research program, that extends well beyond the department’s graduate school bound students, may be a broader appreciation among our graduates of, not only what research is, but how very difficult meaningful scientific results are to attain.

- The dominant practical obstacle to a successful research by this group was the limited exposure of the students to scientific programming (most often, but not exclusively, IDL).

- Given a limit of up to 20 hours per week, students worked an average of 7.7 hours per week over the semester. Both the students and mentors overestimated the anticipated work hours at the beginning of the semester, by nearly a factor of two. Reflecting back on the semester’s effort, students tend to overestimate the number of hours they actually worked.

- Students who claim they want minimal help may not seek it out, sometimes to their own detriment.

- Of the 15 mentors responding to the final survey, 11 stated that the students at least met their expectations for the semester. Of these, 5 students significantly exceeded expectations.

- Total cost of effort (4 months, 18 students, 2249.83 hours worked): $27,560.40

- Any future program should carefully consider timing. One viable possibility may be to run the program during the Spring semester of the Sophomore year, recruit during the Fall semester, offer preparation sessions (including discussions with past participants), and allow one week of full time research before the start of classes.
Recruitment

The response of the APS undergraduate students to the initial announcement of a research opportunity was tremendous. 22 students replied by email the same day the announcement went out, 25 students replied in total. Four other students did not respond directly to the announcement, but requested to participate. A follow up email was sent to all these interested students. It asked for further information on the students’ standing, experience, and interests. 23 students in total responded to this request and were considered for research positions.

Simultaneously, an email describing the undergraduate research opportunity and recruiting mentors was sent to all APS teaching and research faculty and postdoctoral researchers. A duplicate email was sent four days later to all LASP researchers. These faculty and student recruitment emails are included in Appendix A.

The APS email generated 11 responses (7 self-paired with students, 4 without a specific student in mind) and the LASP email generated an additional 9 responses (3 self-paired with students). Each mentor provided a short project description and a statement of project needs. Students were paired with mentors, either by the prior self-pairing of participants (all self-pairings were honored) or based on an assessment by the organizer of matching scientific interests and student capabilities. One faculty mentor declined participation, based on his unfulfilled need to interview the students, this mentor was replaced and the student continued in the program. Another faculty member declined further participation, based on the expectation of additional workload through participation. The self-pair student of that mentor continued to participate for about half of the semester before dropping out. Survey responses from this pair are not included in the compiled statistics below (although some insightful comments are). Additionally, one self-paired mentor and student withdrew at the beginning of the term due to the mentor’s anticipated prolonged absence.

Thus, eighteen students and faculty fully participated for the full duration of the semester.

Four students expressing an interest in the program could not be supported.

Lessons learned:

- **Begin recruitment of both students and faculty earlier.** In the exit debriefing (Week 15 group meetings below) several students suggested that the research pairing be completed before the end of the previous semester to allow class schedule adjustment based on the work-load expectations of the mentors and some initial period of research (~1 week) before the start of classes.

- **We did allow research to begin before the start of classes as suggested above, but only 3 students took advantage of that opportunity,** likely because recruitment took place in the wake of previous plans. Moreover, work on the projects ramped up
rather slowly with the average number of hours worked not peaking until 4 weeks into the semester (see work hours plotted below).

- Send only one email out to students, requesting vitae information and an interest statement right away.
- Make it clear to the faculty beforehand how the pairing will be done. It seems impractical to implement an interview scheme for a group this large.

**Student demographics**

The students selected for this research opportunity met three criteria: they were all APS majors, none had prior research experience, and all had previously taken or would be enrolled in ASTR2600 or ASTR3800 during Spring 2010 semester. Class standings of the selected students were:

2 5th-year students, 8 seniors, 7 juniors, and 1 sophomore,

although the students’ self-identified status (or expected graduation dates) are much lower,

0 5th-year students, 3 seniors, 10 juniors, and 5 sophomores.

Only one member of the group graduated at the end of the research semester.

9 of the students who participated were also regular attendees of Beyond Boulder [http://beyondboulder.pbworks.com](http://beyondboulder.pbworks.com).

The academic standing of this group of students was somewhat lower than those typically involved in undergraduate research. Their average GPA was about 3.0 with a high of 3.8 and a low of 2.3. Only 3 students had GPA’s greater than 3.5 starting the semester.

![Student GPA entering the research semester, mean (dashed) and median (dotted) over-plotted as vertical lines.](image)
Participants and projects:

Chris Anaya – John Bally (CASA)* – Cataloging Protostellar Jets  
Srikar Appana – Laila Andersson (LASP) – Auroral Substorm Characterization with THEMIS  
Robin Beck – Peter Pilewskie (LASP)* – Solar Photometer Calibration  
Kristina Davis – Shri Kanekal (LASP) – Electron Loss from the Outer Van Allen Belt  
David Dyer – Makenzie Lystrup (LASP)* – IR observations of the Jovian Aurora  
Drew Hogg – Xiaohua Fang (LASP) – Interaction of Solar Protons with Earth’s Atmosphere  
Stephen Matey – Mark Rast (LASP)* – Sunspot Center to Limb Variation  
Amir Mirfakhrai – Fran Bagenal (LASP)* – New Horizons Observations of the Gas Giants  
David Morris – Guy Stringfellow (CASA) – Observing Star Forming Regions at SBO and APO  
Quinn Mueller – Peter Delamere (LASP) – Hybrid Models of Giant Planet Magnetospheres  
Dan Olsen – Larry Esposito (LASP)* – The Jets of Enceladus  
Cortlandt Pierpont – Mihaly Horanyi (LASP) – Lunar Dust: Reanalyzing the Apollo Rover Movies  
Matt Reisman – Beth Fernandez (CASA) – Contribution of Early Stars to the Radio Spectrum  
Katie Rice – Marty Snow (LASP) – Solar Flares in X-Ray and UV  
Matthew Sassu – Andrew Jones (LASP) – Designing a Silicon X-ray Detector  
Shelbe Timothy – Nick Schneider (LASP)* – Simulating Spectra of the Martian Atmosphere  
Barton Tofany – Alex Brown (CASA) – Starspot Photometry with Kepler

Lessons learned:

- Completely unanticipated difficulties encountered in office and computer allocation. Most students completed projects using a personal laptop, but access to data was sometimes difficult.
- **Note: the two lowest performing students (did not complete oral presentations) were self-paired.**

Weekly meetings between students and organizer:

Group session meeting times were determined via email exchange. Class conflicts dictated two sessions: Tuesday 8:30 – 9:20am and Thursday 5:00 – 5:50pm. Students were asked to attend one session per week. No one had conflicts with both sessions. Attendance was at the ~75% level (unofficial – attendance was not taken at the sessions). First half of semester focused on strategy and skills, second half allowed opportunity for each student to give an oral presentation of their work and be evaluated by their peers and the organizer. Representative slides from the talks can be found in Appendix B.

Attendance at the group meetings did not count as research hours, and was *not* supported by pay. **Participation in the group sessions was facilitated by enrollment in one unit of independent study. Both the syllabus and grading rubric for the independent study should have been more formalized.**
Listing of weekly discussion topics and activities:

Week 1: Introduction, mechanics, discussion of required individual initiative necessary for research success.

**Lessons learned:**
- 8 students had already completed either ASTR2600 or 3800, remainder concurrent.
- **13 of the 18 students had previously searched unsuccessfully (or successfully only in the context of this program, i.e. as self-paired participants noted above) for research opportunities in the department**

Week 2: Comparisons between mentors’ written project descriptions and student researchers’ oral project descriptions; comparison between mentor and student expectations (time, product vs. experience)
Student comments: **“Mentor could do this problem in a day.”**
**“Learning problem context will produce better product.”**

Week 3: REU opportunities – personal essay content, making contact with specific REU programs

Week 4: Interfacing with IDL – command line, list file, PRO, FUNCTION, .run, .rnew, stop, .con, retail, memory allocation, memory sharing with PRO, memory release, for loops on the command line, if statement to comment out code portion, array syntax, intrinsic functions

Week 5: Web research – NASA ADS, ISI Web of Knowledge, identifying review level articles (Annual Reviews, Space Science Reviews, Living Reviews); the referee system (journal vs. conference papers, eprint arXiv)

Week 6: Connections between student research projects and last decadal survey

Weeks 7 and 8: Constructing and delivering a scientific presentation.

Week 9 – 14: Student presentations (Appendix B). All but two students delivered talks.

Week 15: Debriefing
Lessons learned:

- Week 2 activity comparing the mentors’ and students’ understanding of the research projects should be expanded as an “ice breaker” activity.

- REU discussion: There is an apparent reluctance on the part of many of our students to apply to a range of REU opportunities beyond Boulder.

- Lessons on presentation skills should have included an example 25-minute talk, with a post talk evaluation and discussion (using the same evaluation form as that used in evaluating the student presentations). This should be done on the second day, after the discussion of reading materials about giving talks on the first.

- Students giving early talks have greater difficulty, both putting the work into context and summarizing personal efforts.

- Clearly state talk requirement for independent study grade at beginning of class. *Use instructor evaluation of talk, but not students, as basis for class grade. This change is a bit problematic. While it provides concrete grading, it may discourage somewhat the free-flowing constructive criticism that was fostered as part of the looser structure employed.*

- After the talks, the students cited the IDL hints and Web based literature search topics as the most valuable part of the weekly discussion sessions.

- The one period session on the connection of the students research with the previous decadal survey was a disaster because very few students bothered to read the executive summary of the decadal survey even though it was assigned and is quite readable.

Early (entrance) survey results:

The following survey questions were asked after initial meetings between advisors and students. 15 of 18 mentors responded, all 18 students responded. Sample comments are selected and edited to shorten and remove names. The comments were chosen to represent the range of responses, not the frequency of them. They are not quoted verbatim, but an attempt was made to preserve content and flavor. Survey questions, as distributed, can be found in Appendix A.

NOTE: These surveys were administered loosely and the results are only discussed qualitatively; they have not been analyzed for statistical significance, though possible inferences based on the survey responses and on the group discussions with the students are noted. Red distributions for students’ responses, blue for mentors’. Mean values are indicated with dashed vertical lines, median values with dotted.
1. Student: How prepared do you feel to undertake the research ahead?
   Mentor: How prepared do you feel your undergraduate student is to undertake the research ahead?

Comments:
Students:
- I feel like my mentor has given me all the material I need for success, but I am lacking a lot of the basic knowledge needed to just crank out some answers. It seems like every hurdle requires hours of research and careful critical thought to overcome. It is definitely a paradigm shift from other jobs.
- My research involves extensive programming in IDL, which I do not have much experience in yet. However, between the IDL class (ASTR2600) and help from my mentor I believe that it will not pose a problem.
- I am inexperienced, but feel comfortable asking my mentor for help.

Mentors:
- My student has good basic IDL skills and he learns quickly. He of course does not have extensive coursework yet in physics and mathematics, and for that reason I have designed a data analysis project that will allow him to get his feet wet with research and expand his skills, in accordance with his current skills.
- I think the student is basically prepared, and more importantly is highly motivated. I rate him a 6, because skills need to be honed. We will see how motivation is balanced against productivity at the end.
- Lots of enthusiasm and ready to learn

Lessons learned:
- Going into the semester mentors had a slightly higher assessment of the students then they had of themselves.
- Assessment of preparedness by both students and mentors changed dramatically over the semester (see Question 1 on the exit survey below).
2. **Student:** How confident are you in your understanding of your research goals?

**Mentor:** How confident are your students in their understanding of the research goals?

![Graph showing confidence levels]

**Comments:**

**Students:**
- I understand 75% of the research goal. The last 25% is still a little confusing to me, but I am not overly concerned about it at the moment.
- My mentor has talked with me about what he has envisioned for this project but there is still plenty of room for my own exploration.
- I know the scientific goal that I would like to meet, but I am not sure what it involves work wise.
- I understand the basics of what we’re doing, but not exactly why.

**Mentors:**
- I think the student understands that there is an initial investment of time required before there will be payoff in end products.
- Aspects of the research program are dependent upon initially qualifying the capabilities of the spectrograph and the imaging camera. A refocusing of aspects of the program may be required.
- Student seems to be able to see the next step in process as we move along.

**Lessons learned:**
- *Both students and mentors started the semester fairly confident that the goals were understood.*
3. **Student:** To what extent are your goals this semester a specific product (paper, presentation, discovery)? To what extent can your goals be described more broadly as experience?

**Mentor:** To what extent are your student’s goals this semester a specific product (paper, presentation, discovery)? To what extent can their goals be described more broadly as experience?

![Graph showing experience and product over time]

**Comments:**

**Students:**
- I think it will be impossible to avoid getting experience if I am able to produce a quality paper or poster. Both the experience and the end product are important to me, but if I focus on the end product then I will have had to earn significant research experience producing it.
- My mentor and I have talked about the project’s long and short-term goals. Short-term goals are primarily for me to gain experience. Long term, if I enjoy this research and continue through summer a paper will eventually come about.
- My work will be mostly an experience. However, I would like to have something more concrete at the end of the project. I’m not sure if my work will be able to be put into research paper format or not yet, but I am hopeful that I will have the opportunity to do so.

**Mentors:**
- The primary goal is to get exposure to various aspects of doing research: some data analysis, some interpretation, and some writing about results and methods.
- This would fall under ‘experience’ and I think it’s really important, as this experience can be a springboard for further research.
- The student and I are looking at this over the long term, perhaps developing the project into a senior thesis.
- I am centering the tasks on specific research tools and capabilities, but the student’s work is important in moving this research forward.

**Lessons learned:**
- Wide ranging opinions on question of experience versus product, but there is a problem with this question as it suggests exclusivity of the two.
- Mentors bimodal, students unsure.
- *High expectations by some students to produce publishable results. Possible sociological implications – research experience can teach non-science career graduates not only what research means but how difficult scientific progress is.*
- How to temper hope with realism? Unfortunately I did not follow up this question in the final survey with a question about satisfaction or disappointment.
4. **Student:** How much independence would you like in defining and conducting your research?  
**Mentor:** How much independence would you like your student to have in defining and conducting their research?

![Graph showing independence levels for students and mentors]

<table>
<thead>
<tr>
<th>Students</th>
<th>Mentors</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would like as much help as possible. They should rely heavily on me for help.</td>
<td>I would like to work very independently. They should be able to work very independently.</td>
</tr>
</tbody>
</table>

**Comments:**

**Students:**

- I am slightly concerned about being able to finish a paper or poster in time if I work independently.
- I would like to work independently with minimal help, nothing more than being pointed in a direction. *This student turned out to be the least successful student in the program – worked the fewest hours and did not deliver a talk.*
- Ideally, I would like to be able to get help when (or soon after) I need it, but for the most part I feel that I can handle the analysis on my own as long as the instructions are clear.
- I like independence after I feel I know the ins and outs of what I do. I’m not quite there yet.

**Mentors:**

- The goal is to enable them to reach 8–10. Presently at 5–6.
- I’m testing how well the student can manage tasks independently.

**Lessons learned:**

- Mentors lean toward independence, students toward help.
- One mentor noted that the question has a problem. Defining and conducting are two very different skills: he gave a 3 to defining and an 8 to conducting.
- *Students who claim they want minimal help may not seek it out, sometimes to their detriment.*
5. Student: How many hours a week would you like to work on the project?
Mentor: How many hours a week would you like your student to work on the project?

Comments:
Students:
- I can spend a little more time on the project than the minimum. This will get very
difficult toward the end of the semester, so I hope the lion’s share of the work is
done toward the beginning of the semester.
- Honestly I would like to work the maximum, but I do not know how reasonable
that’ll be as the semester progresses. *(This student reported at the end of the
semester that his grades suffered as a result of participation in the program –
‘should have been studying when I was doing research’)*

Mentors:
- As many as possible.
- I am trying to keep the amount of work within the 10 hours he agreed upon, and I
ask him if the amount of work I give him in a week is close to this amount.
- I know my student wants to work the maximum number of hours he can. He is a
mature student and I trust that he will put in the hours needed to make good
progress. I am more concerned with progress than with the number of hours.

Lessons learned:
- Wide range, but mean and median values are between 13 – 15 hours.
- Likely heavily influence by initial announcement of opportunity for 10 – 20 hours.
- High levels of enthusiasm starting the semester.
- Black curve shows the student’s actual average-weekly-hours over the 16-week
semester. *The average number of hours-per-week actually worked by the
students over the course of the semester (7.7 hours) was nearly a factor of two
lower the average desired-number cited by the students (13.9 hours) and
mentors (13.1 hours) when starting out on the projects.*
6. **Student:** How many hours a week would you like to meet with your research mentor?
   **Mentor:** How many hours a week would you like to meet with your student?

![Graph showing meeting hours](image)

Comments:
**Students:**
- Would prefer brief meetings all three days I work to discuss what I am doing and assess what I will be doing in the future based on my current progress.
- No specific number of hours, just meet somewhat regularly and accommodate each other’s schedules.

**Mentors:**
- About 1, but ideally in several shorter meetings when they get results or have questions.
- 2 hours at least, more if necessary.
- We also communicate by email and telephone.
- Student also meets frequently with other members of my research group.
- I try to be available for any questions whenever he is here and we talk each day about that day’s task.

**Lessons learned:**
- One or two hours are agreeable. Students would probably like two.
- Mentors in general want to be readily available to the students when they need help.
- Some mentors very hands on, others not. Some students were embedded in a research group. *No direct evidence (heuristic) that any of these environments works better or worse than the others.*

7. **Student:** What type of help would you like from your mentor?

(Note: answers to this question are quoted somewhat more completely.)

- I would like occasional help with difficult problems. I try to find the answer myself and with the help of my undergrad peers and if I absolutely can’t find the answer then I send my mentor an email.
- More guidance and answering questions.
- Definition of specific goals so that I am sure to produce what he wants out of the project.
• I like getting a general idea or starting point for what my goal may be, and then be given tips or hints for help as I need them along the way. I only sometimes worry that I may not be helping the mentor as much as she expected I would.
• Guidance, to help me prepare for what the field of research is like on the front line.
• Any.
• Guidance, and help with understanding ‘jargon’.
• Just good explanations of what he actually wants me to do.
• I would like some feedback to make sure I’m going in the right direction and that I fully understand what I am doing and its significance.
• Clear specific goals. How my work fits into his. Specific information, as I am here to program and produce something.
• I primarily require assistance with technical issues such as programming, but also an experienced opinion on how to conduct research would be appreciated.
• I would mainly like my mentor to give me a sense of direction when I am lost, as well as a goal to accomplish.
• I will probably need help with the programming.
• I would mainly like help in learning what I need to do and why.
• Just a nudge in the right direction. A bit more conversation regarding the theory behind the project, implications of it, etc.
• General assistance, tips, enthusiasm in the field.
• Pointers of what to do if I am stuck and pointing me in the proper direction. Clear instructions of what she wants me to do on a given day.
• Answer specific questions about the mechanics of my research. Broad discussions.

Lessons learned:
• The greatest difficulty students face when initially starting out in research may be appreciating its open ended nature. This combined with a strong desire to quickly produce publishable results leads to some level of anxiety.
• This lesson, the difference between research and problem sets may be the most important of the experience.
• Students start out uncertain of their programming skills.

8. Mentor: What type of help do you expect your student will be in most need of?

(Note: answers to this question are quoted somewhat more completely.)
• Programming: Fortran and IDL
• Understanding the big picture
• Understanding the physics and translating the ‘jargon’. Interpreting results.
• Running IDL, discussing the science, combination of the two.
• Project definition.
• Logistics, computing, IDL.
• Understanding the science.
• Logistics with programming and project definition.
• Technical support in installing and running an instrument.
• Getting started. Web sites and how to get information from them. IDL.
• Time management. Learning data reduction scripts. Encouragement to commit to the effort.
• IDL and general programming skills.
• Specific instruction in the use of software tools. Training in target recognition.
• Surprised by lack of understanding of exponential, time-constant, scale-height concepts. IDL.
• General guidance.

Lessons learned:
• *Mentors aim to provide scientific content and tools; students want specific tasks, directions, and goals.*
• IDL is key.

**Hours worked:**

Individual student hours were highly variable over the semester (grey curves above). *The average number of hours spent by the group on research in any one week ramped up slowly to a maximum of 9.8 over the first four weeks of the semester, and then slowly declined* with a brief uptick over spring break (marked by vertical blue line above). Week 0 was the week immediately preceding the start of classes; only three students took advantage of an early start.

Lessons learned:
• *Even the peak average weekly hours worked by the students (9.8 hours) lies well below the desired number cited by the students (13.9 hours) and mentors (13.1 hours) when starting the projects.*
Presentations:

Each student (with only two exceptions) gave a 25-minute talk on their research: scientific background, project details, and implications, followed by 5 minutes of questions. The class used an evaluation form to assess the quality of these presentations. The form is included in Appendix B, along with sample images of the presentation slides.

Late (exit) survey results:

The following survey questions were asked after the semester was completed (although some students elected to continue into the summer). 15 of 18 mentors responded, and 14 of 18 students responded. Sample comments were selected and edited to shorten and remove names. The comments chosen represent the range of responses, not the frequency. They are not quoted verbatim, but an attempt was made to preserve content and flavor. Survey questions, as distributed, can be found in Appendix A.

NOTE: These surveys were administered loosely and the results are only discussed qualitatively; they have not been analyzed for statistical significance, though possible inferences based on the survey responses and on the group discussions with the students are noted. Red distributions for students’ responses, blue for mentors’. Mean values are indicated with dashed vertical lines, median values with dotted. Some questions in these surveys did not overlap.

1. Student: How well prepared do you feel you were for research before starting?
   Mentor: Coming into the project, was your student’s preparation adequate?

Comments: Should IDL (either through ASTR2600 or ASTR3800) have been a prerequisite rather than co-requisite for participation?

Students:
- I did not use IDL (2 of 18 students).
- I recommend IDL as a pre-requisite because I would not have been able to produce much in the way of results without my IDL experience from 2600.
- 2600 pre-req, 3800 co-req.
• I took ASTR2600 as a coreq but I feel I learned fast enough that it did not hinder my work.
• It would have been a lot nicer if I had had more IDL experience.
• **Total on student IDL question: Pre-req 7, Co-req 3, Recommended 2, No clear response 2.**

Mentors:
• Quick learner, but IDL was a steep learning curve.
• We learned more IDL together than he did from class.
• Some programming course (IDL, Fortran) would have meant fewer difficulties with the research project.
• Pre-req – student can hit the ground running, co-req – more junior students can participate.
• Co-req was okay for my student.
• Motivated students – co-req works, less motivated students really need pre-req.
• If meant as introduction to research then having pre-requisites could undermine that.
• Would help, but worry about a formal pre-req.
• My student was distracted by classes.
• Student should focus on science rather than be “fully” proficient in the tools required.
• **Total on mentor IDL question: Pre-req 7, Co-req 2, Recommended 0, No clear response 7**
(exceeds 15 because response of the mentor of the withdrawn pair is tallied as vote for pre-req)

Lessons learned:
• *There was a dramatic reduction over the semester in the assessment of preparedness both by students and mentors (see entrance survey Question 1)*

2. **Student:** How worthwhile do you think a research opportunity during the semester is (as opposed to summertime only)?
   **Mentor:** How worthwhile do you think a research opportunity during the semester is for the students (as opposed to summertime only)?

![Graph showing student and mentor responses]

**Comments:**
**Students:**
• Research experience as soon as possible is essential – if not summer after freshman year then sophomore year.
• It was either doing this, which I really liked, or working in the restaurant because I have to pay rent and such.
• It teaches very difficult and complex time management and prioritization.
• Doing research with classes going on is more like real life providing an exercise in time and thought management.
• It should be communicated more clearly to the students that they should consider this experience equivalent to a 4 credit hour class so that they can budget their time properly beforehand.
• This was an extremely worthwhile and priceless opportunity; it completely changed my views on research. The benefit of it being during the semester is that we can do other things during the summer, or continue our research. If this were simply a summer REU, fewer students would be able to do it.
• It helps convey the urgency of real-life situations when there is so much going on at the same time.

Mentors:
• Good to be able to take initial research more slowly, with fewer hours per week.
• It helped me assess his potential, and we will hire him this summer.
• Mentor needs to set realistically small goals to make research during the semester worthwhile.
• Classes often got in the way, which is understandable. Not clear that the student can put in the needed hours.
• Opportunity is excellent for dedicated and/or prepared students and not very useful for those prodded into being involved.
• Students likely to have more contact time during the semester (less faculty travel).
• Likely varies between students. *Maybe there should be a higher minimum GPA.*
• Semester-time opportunities help them be more competitive in applications for REUs.
• Simultaneous exposure to pedagogy and research is worthwhile. Helps the student see real world applications of some of what he was learning.

Lessons learned:
• *Generally supported by students based on enthusiasm to get into research early, a need to work some job in any case, and the time-management skills learned.*
• *Generally supported by mentors in providing an integration of course-work and research, but there remain significant concerns that the amount of time available to the student during the semester for research is too small.*
3. **Student:** How interested would you have been in this opportunity if it had been linked to units (course credit) rather than pay, say 1 credit for every three hours worked per week?

**Mentor:** Do you think it would make more or less sense to offer this opportunity linked to units (course credit) rather than pay, say 1 credit for every three hours worked per week?

![Graph showing interest levels]

**Comments:**

**Students:**
- Either way I would have done it, just for the experience. Pay and credits are a bonus.
- Would have been better able to balance work and course load.
- I do not need any more credits, but I do need money.
- Credit is not important to me.
- Pay is very good.
- If the funding isn't there in the future, I would love to see it established as a for-credit course.
- Pay was a great incentive and made the experience seem more like work than another class.
- Without the pay I would have had to retain an outside job and the time commitment may not have been doable.

**Mentors:**
- Would be good for the student to get some academic credit for the huge amount of work involved.
- Money is a good incentive.
- It is a very useful skill to be able to partition time between work and education.
- Require a paper at the end of the semester and assign credits based on the quality of the paper?
- Students appreciate being paid. Many of them need to make ends meet, and having a job, doing research for credit, and taking classes may be too much to ask.
- Pay gives a real emphasis. They are also getting 1 credit.
- It is important that the experience is different from taking a class.
- Pay and possible honors thesis. I don’t recall anyone having difficulty collecting sufficient credits to graduate.
- Pay gives the sense of a professional effort, not just an educational one.
- On applications they can indicate a paid research position rather than a course.
• Credit places a greater obligation to teach.
• Students may be less accountable for credit than pay. Filling out time card every couple of weeks at least makes them pause and consider how much time they spent doing research.

Lessons learned:
• Student question has a flaw. Students can be very interested because they very much want to do research independent of the pay/credit distinction or because they think the credit option is better.
• Students can use/need the money.

4. Student: Would you recommend this experience to another interested student?

Comments:
• I already have and many people want to do it.
• The experience was an eye-opener and helps students zero-in on what they want and/or are good at that much sooner.
• I have learned a lot, gained experience, made contacts, worked with some great scientists, and made my own schedule.
• Very educational, and good prep for future employment.
• It is a good way for students to decide if research is something they really want to do.
• This was an amazing opportunity, especially for a student who might not have the GPA for more competitive REUs. It is also great for students who get into REUs because they go in with more experience.

Lessons learned:
• Very high level of student enthusiasm.
5. Student: Were the weekly group sessions useful?

Comments: (specific examples?)
- List of useful advice/tools provided as cited by students:
  - What the job is “really like”
  - Time management skills
  - Public speaking tips, talk strategies
  - Web sites for citations/references
  - Science discussions
  - Discussion of research in general
  - Opportunity to express concerns
  - Time to talk with other students about their projects
- Talks were most beneficial
- Didn’t really affect the work I did one way or another.
- Meetings need more focus, maybe more focus on project updates.
- For the most part the group sessions seemed superfluous.

Lessons learned:
- Students found the weekly group sessions at least somewhat helpful.
- Opportunity to hear about peers’ research was cited most often as the primary benefit.

6. Student: How important was the opportunity to give an oral presentation to the overall experience?

Comments:
- Not very to the overall experience, but it was a great experience for future talks we might give.
• Very valuable but perhaps too time consuming and that time may have been spent talking about research.
• Gave me a good idea of what to work on.
• Pointed out flaws in my own understanding of the material
• A completely exhilarating experience. I learned to really grasp the fundamental physics behind my project.
• Helped me understand more thoroughly what I was doing and why.
• Hearing about what others were doing gave a better perspective on the various paths research can take.
• It gave me a defining goal to reach and helped me understand what I’ve been doing all semester.
• Getting feedback on the presentation really opens your eyes to where your faults lie as a presenter

Lessons learned:
• Very enthusiastic response to the opportunity to give an oral presentation.
• Oral presentation provides focus and definition to the project.

7. Student:  Do you think a research paper writing component should be added?

Comments: (If only one was possible, which would you find more useful, an oral or a written presentation of your research?)
• Only one or the other.
• Oral presentations test more skills.
• There are other classes that teach scientific writing skills.
• I get a lot of experience writing, but not a lot of science presentation experience.
• Both would be beneficial.
• It would make for a richer experience overall.
• Would be nice if the student was given the choice to do one or the other (or both).
• Paper writing would probably occur near the end of the semester when students are swamped with finals.
• Research paper may be more valuable because mentors suggest them as part of the project anyway.
• Written would be more beneficial because we will most likely publish papers before giving any talks.

Lessons learned:
• The opportunities for oral scientific presentations are more limited than those for written ones, and so the students largely prefer oral to written presentation of their projects
• The importance of scientific presentation throughout one's scientific career should be more clearly discussed with the group (last comment above)

8. Student: How engaged was your mentor in mentoring you?

Comments:
• I definitely recommend my mentor for inexperienced undergrads. He was great!
• My mentor was very busy and very hands-off, but that taught me to ask my own questions and derive my own answers and evaluate their importance.
• You could tell he enjoyed sharing his knowledge.
• He was there whenever I had questions.
• I didn’t really work with my mentor directly, but the staff I did work with were incredibly helpful.
• Guided me when needed but also let me struggle through problems so that I solved them myself.
• We met when there was a stumbling block, but for most part the work was independent. (Note: mentor of this student was frustrated by lack of contact)

Lessons learned:
• By end of program students have a fairly sophisticated appreciation for the mentors dual role.
9. Student: How realistic were your mentor's expectations?

Comments:
- Gave me a rough goal, but whatever I got done was fine.
- A little more sophisticated in IDL than I am capable of after 1.5 semesters of class.
- Sometimes he would give me a lot to do, but I realize now that he didn't expect me to do it all that night.
- I felt like sometimes I may have not had enough to do.

Lessons learned:
- Question is flawed – out of touch can mean either too much or too little.

10. Mentor: How would you rank your students performance relative to your expectations?

Comments:
- Completed 2 of 3 parts, about as expected.
- Student probably could have worked more and gotten more accomplished, but I think that should be based on her self-motivation rather than my hopes for the science output.
- Student as a lot of programming experience coming in – appreciated.
- I would have like the student to ask more questions, both on the debugging and physics of the problem.
- My student was basically AWOL.
- I have yet to see any results...
- My student was going through a family event this semester, so that was a factor. (Note: This is known to be true of at least two students, one who performed well despite and one whose performance was marginal.)
- To little time on task.
• Class obligations did limit my student’s engagement.
• Student was very enthusiastic and seemed to enjoy doing research.

Lessons learned:
• A rather disappointing experience for a number of mentors.

11. Mentor: How engaged was your student?

Comments:
• I don’t think the project ended up being too high a priority for my student.
• Engaged but did not initially recognize the level of effort and thought required for independent research.

Lessons learned:
• Nearly all levels of engagement noted.
• The amount of focus and attention necessary to make progress, and the contrast between incoming expectations of success and actual achievements, may be a key reason to involve non graduate school bound students in research – a reality check on what scientists are actually trying to do and how hard it is to achieve that is much better delivered by experience than words.

12. Student: Overall my research project was:
Mentor: In retrospect, how would you rate the research project you had in mind for the student?

Comments:
Students:
• I learned a lot and I had a lot of fun.
• Did not finish what I wanted to finish (yet).
• Not enough tasks given.
• I didn’t have great preparation for plasma physics, but I learned a lot!
• I definitely felt overwhelmed at times during the project. (Note: student ranked this 7.)
• Just challenging enough that I learned a lot and it wasn’t boring.

Mentors:
• Open ended so student could push as far as and as quickly as comfortable.
• If student had a better grasp of IDL coming in, we could have concentrated more on physics and execution rather than getting programs to work.
• Most of the time was spent duplicating earlier results to verify student’s code, rather than moving into student’s project. While this is important in real life, we didn’t have enough time to really simulate real life.
• Project was hard, but exposed the student to a “real” research problem not a “toy” problem.
• The experience the student gained by a “false start” (out of the student’s hands) was quite valuable, but not very productive for the original intended project.
• Not sure “too hard” is the right choice of words, but the project had to be modified somewhat to ease student into material and computer requirements.

Lessons learned:
• Both mentors and students assessed the projects to have been somewhat too hard.
• Intervals of feeling overwhelmed a common experience for students.

13. Student: Do you believe that doing research this semester negatively or positively impacted your performance in other classes this semester?

Comments:
• It was easy to balance research with coursework
• Only once did I do research when I should have been studying
• Preferred to do research, but never had to chose between them.
• Making my own work schedule was good. The only thing that may have impacted school was that I enjoyed working and felt it more important than some classes.
• Time spent on research did end up taking some time away from study.
• Project definitely took my mind away from classes at times.
• I didn’t realize the extent of the time commitment at the beginning and fell behind.
• I had to drop a class, but I think it was worth it.
• I am only taking 14 hours this semester, but I can see how taking 18 and research could be a problem.
• Positive impact on IDL. Research helped a lot with programming.
• I got to see some principles we learned in classes in action.
• It was so nice to use my time for something pertinent to what I am studying rather than working as a cashier.

Lessons learned:

• **Negative impact of research must be mitigated for a viable program, although the students overwhelmingly would recommend participation despite.**
• **Weekly group meetings should stress prioritization and help with time management.**

14. **Student:** How many hours per week (on average) do you estimate you spent on research (this will NOT be compared to your time card)?
**Mentor:** How many hours per week (on average) do you estimate that your student worked?

![Graph]

Comments:
Students:
• It varied widely from week to week.

Mentors:
• More hours in the beginning, less at the end
• Towards the end, it all went to the presentation. (Note: this from mentor of one of two students who in the end failed to deliver a presentation.)

Lessons learned:

• **Mentors accurately perceive students to have worked many fewer hours than students perceive themselves to have worked.**
• Black curve shows actual average weekly hours worked hours during the 16 week semester – **students overestimated how many hours they put in.**
• **Preparing presentations for group meetings cut into actual research.**
15. Student: How many hours per week (on average) do you estimate you spent with your research mentor?
Mentor: How many hours per week (on average) do you estimate you spent with your student?

Comments.
Students:
• 1 hour with mentor, 6 – 7 with other group members.
Mentors:
• The total was a bit less because she didn’t always come in.
• Student demonstrated low interest in or time for meeting. May have perceived me as too busy.

Lessons learned:
• Students remember spending slightly more time with their mentors than the mentors do – mentors would have liked to spend much more time with students.

16. Student: What was the most helpful thing your mentor did?

• Helped a lot with IDL
• Explained concepts
• Recognized spinning wheels and redirected me
• Constant contact
• Gave me lots to read and let me ask a lot of questions
• Was always available to answer questions
• Let me loose to do what I could, helping/guiding/focusing when needed
• Provided in depth explanation of governing equation
• Gave me projects so that I was always busy
• Hinting when programs didn’t work
• Was patient and understanding when I was struggling to be effective.
• Listened to problems I had and tried to help usher me through them while still letting me think for myself.

Lessons learned:
• These range from the concrete to the subtle. Students like a hands off/hands on approach. (Note: we did not talk about what mentors were doing right or wrong in the group sessions, so these are really from the heart, not influenced by what they are “supposed” to want from the mentor.)
17. Student: What type of help would you have liked, but did not receive, from your mentor?
   - N/A, I can’t really think of anything, I got all I needed, I got all the help I needed just by asking.
   - Recognize wheel-spinning earlier.
   - A little nudge here or there.
   - He helped me a lot, when he couldn’t he sent me to people that could.
   - Time management help.
   - Possibly weekly scheduled meetings rather than random intermittent ones
   - A little more help with IDL. More direct help with IDL.
   - Bigger picture briefing.
   - More applied help with the programming rather than the theoretical aspect.

Lessons learned:
   - Very hard to generalize individual needs of the students, but overall the mentors involved are judged by the students to be well engaged, providing roughly the right hands on/hands off combination.

18. Mentor: What type of help, outside of your mentoring, would have most benefited your student?
   - IDL/programming (Note: this was explicitly mentioned by 5 of 15 respondents.)
   - Weekly progress checks in the group meeting
   - Basic astronomy as a pre-req
   - Address social challenges (too passive, too independent, not enough effort and thought committed) in group meeting.
   - Critical thinking/problem solving skills.
   - Presentation skills, practice communicating scientific results.
   - I have no idea what would have helped.

Lessons learned:
   - “My student was bright and capable, but never took off.”

19. Student: In order of decreasing importance, name three things that you got out of the research experience?
   - What is done in research, IDL knowledge, how university employment works
   - Experience thinking like a research scientist, something to put on my empty CV, exposure to interesting science and scientists
   - Experience (resume), better idea of what scientists do, continued employment
   - Contacts, experience, an idea of what I want to do for my career
• Experience, time management skills, money  
• Confidence in management, body of physics knowledge, networking  
• Networking/ real world experience, scientific problem-solving strategies, IDL experience  
• Experience, money, school credit  
• An understanding of how research works, the rewarding experience of adding to contemporary science, contact with professional researchers  
• Understanding of what it means to do research, research techniques and practices, time management skills  
• How to work in a research environment, tackling problems with no specific answers, balancing research with class  
• General taste of what research is like, programming/IDL experience, time management skills  
• Experience with research, information learned about research topic, IDL experience.  
• Practical experience, work with a faculty member, science related job.

Lessons learned:
• The emphasis on “contacts/networking” surprised me.

20. Student: Comment: What would help improve the program?  
Mentor: What would help to improve the program?

Students:  
• More solid goals  
• I wouldn’t change a thing.  
• Knowing IDL  
• A better ideal of the time commitment going in  
• Possibly a research paper instead of presentations to allow for other things to be explored in class.  
• Start projects a couple of weeks before semester begins.  
• Extension of program into future years (by credit or pay)  
• Option of writing a research paper  
• Any student should have the opportunity regardless of GPA or career path.  
• Increasing the variety of projects a student can take on.  
• More guidance from the very beginning.

Mentors:  
• Clarify students capabilities for mentor going in to bring expectations in line and enable mentor to focus initial attention where needed.  
• A required written report of research results.  
• Move program to summer so that student has more time to work on project.
• Keep at it! Students may languish without a group event/training/meeting and 
  shepherd.
• More than one talk per semester.
• Time management preparation
• Opportunity to observe my student interacting with others (attending 
  presentation).
• More coursework and IDL prep so that we could have progressed to the most 
  exciting and interesting part of the research.
• More time for initial preparation by both mentor and student.
• *Informing the students early (Fresh/Soph years) about this program so they can “prepare” and anticipate it, as opposed to stumbling in. Making it a part of the major program solidifies goals and expectations. Then further student-to-student flow of information (Seniors to Fresh) would occur as the program matures. This will attract the more serious students also.*

Lessons learned:
• *Get on the ball with organizing a whole lot sooner.*

Continued research beyond semester:

• 14 of the 18 students continued their research projects with their mentors into the 
  early summer (until June 30th)
• 5 (matey, sassu, davis, bushinsky, dyer, beck so far – will be updated at end of 
  summer) continued beyond that on other resources or were employed as a result 
  of the program.