Evaluation of the California Institute of Technology (Caltech) Global Relay of Observatories Watching Transients Happen (GROWTH) Partnership for International Research and Education (PIRE) Spring 2018 Courses Funded by the National Science Foundation

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Report contents

This report contains results from evaluation surveys conducted to assess three courses offered in Spring 2018:

- ASTRO 498S Astronomy Research Course in "Big Data Surveys" at University of Maryland, College Park
- ASTRO 350 Astronomical Techniques at San Diego State University
- AS6005 Advanced Astronomical Observations at National Central University, Taiwan

Analysis notes: For questions that were answered on a 5-point Likert scale from "strongly disagree" (1) to "strongly agree" (5), response frequencies were categorized in this report to the following three levels: "disagree" (1-2), "neither disagree/agree" (3), and "agree" (4-5).



Response Statistics for ASTRO 498S

Summary: Nine of the 12 course participants completed the course evaluation and one participant partially completed it (total response rate: 83%). This report includes findings from all 10 respondents. Therefore, sample sizes may differ throughout this section.



Course logistics

Summary: Most respondents (6-10) agreed that the course was engaging and experiences in the course were valuable to their learning. They also agreed that the instructor was knowledgeable and enthusiastic about the content and handled questions well.

Instructor demonstrated enthusiasm for the subject matter.

The use of real world data was valuable to my learning.

The course stimulated interest and deeper thinking about the subject.

The opportunity to collect my own data was useful to my learning.

Having special events, such as guest lecturers, enhanced my learning experience.

The course raised challenging questions.

Instructor had a strong command of the subject matter.

Instructor handled student questions well.

Lecture information was presented in a logical, step-by-step order.

Instructor was available to provide assistance during office hours.

Instructor could identify and address student concerns about the material.

Disagree	Neithe	r agree/di	sagree	Agree	e			
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				10				
				10				
				9				
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	4					6		
2		2				6		
0	2		4		6		8	

Course outcomes

Summary: Respondents generally agreed that the course increased their knowledge of course objectives, especially understanding of the research process, data extraction, and understanding publications.

Disagree Neither agree/disagree Agree 0 9 8 8 6 2 8 10 0 6

Increased my understanding of the research process in astronomy/astrophysics. Increased my ability to read scientific publications. Increased my ability to extract data from survey databases. Increased my ability to generate meaningful scientific questions. Increased my overall knowledge of astronomy/astrophysics. Increased my ability to identify and describe key plots in scientific publications. Increased my ability to create effective plots by coding. Increased my ability to design a comprehensive and feasible research project. Increased my interest in becoming an astronomer. Increased my ability to write a clear and compelling research proposal. Increased my excitement and passion for astronomy/astrophysics. Increased my ability to write code for statistical calculations and simulations. Increased my ability to use statistics to determine errors and robustness of results. Increased my interest in astronomy/astrophysics research. Increased my ability to create and maintain a detailed logbook. Increased my ability to cross-match data using different catalogs.

Course impact on respondents' understanding of the research process

Summary: Seven respondents commented that the course helped to increase their knowledge of specific aspects of the research process or of it generally. Two mentioned that learning about the research process was rushed and did not allow for more in-depth learning.

Research process felt rushed due to the course

- This is a tough question to answer because I already had some bit of experience with the research process in astronomy and astrophysics. I think this course taught me to teach myself material quickly and to adapt to new tools and data acquisition methods. The major difference I noticed between my own research and the work in this course had to do mostly with the pace of the work. Because we were trying to finish a research project on a semester time-scale, we weren't able to get a strong foundation in our research topics or get much formal training in the data acquisition or analysis techniques. I sort of felt we were in a bit of a "sink or swim" environment, and this feeling was especially felt when aspects of our project fell through/ when we hit unexpected road blocks.
- This course made me feel that the research process was more haphazard than I had originally thought. It seemed that the professor was more interested in running through the process instead of delving deeper into data analysis and getting good results.

Specific aspects of the research process

- I became aware of the process of generating your own research questions and learned how to review the literature. I also learned how to select the necessary database.
- It made it much more transparent and made me realize that I can come up with meaningful scientific questions.
- Introduced Gaunt charts, taught how to write and approach the idea of proposals and planning projects. Helped teach problem solving for what to do when hitting a road block.
- It has taught me how real research is done from the proposal up through drawing conclusions from statistical analysis of the data.
- I never understood the importance of reading the literature and being on top of the new findings and research.

General understanding of research process

- This course has helped me understand the research process better since we worked on our own projects and had to learn how to deal with problems in data analysis during the project.
- I have a much better idea of how professional astronomers handle and understand data.

Course impact on respondents' interest in becoming an astronomer

Summary: Six respondents reported the course increased their interest in becoming an astronomer, with some noting the course did so through giving them data analysis experience, introducing them to different techniques, or presenting them with new ideas about research in the field.

- Reminded me that I do enjoy research as a whole, regardless of if its my favorite topic in astronomy or not. Showed me just how many different techniques there are to approaching astronomy, from observational to theoretical modelling
- I really liked the data analysis part of this class, so it increased my interest in being an astronomer.
- I am more interested in pursuing astronomy in graduate school now that I have an idea of the types of research performed by graduate students.
- This was my first astronomy research experience, despite being a senior astronomy and physics double major. I have research experience in biophysics, but this course made me realize my real passion is astronomy.
- · It has definitely contributed to me wanting to be an astronomer more.
- Although this course was challenging, it has opened new questions I want to explore, and has made me better at asking new questions.

Course impact on respondents' interest in conducting research in astronomy or astrophysics

Summary: Respondents commented that the course increased their interest in conducting research in astronomy/astrophysics, with some noting this was due to the data analysis experience, increased programming skills, and exposure to new topics.

- Reminded me that I do enjoy research as a whole, regardless of if its my favorite topic in astronomy or not. Also, reminded me that time-domain astronomy is
 technically the field I want to study. brought to light the idea of using large surveys to find asteroids and comets and to study solar system bodies, which I hadn't really
 considered as use of surveys.
- This class increased my interest in pursuing research in astronomy.
- I am more interested in research now that I have handled data first hand and improved my programming skills.
- It has increased my interest in conducting research in astronomy. It's also made me realize that I can do this completely on my own. While University resources would be helpful, they are not necessary to conduct meaningful scientific research.
- It has made me more interested in time-domain astronomy research.
- I now understand that I am more inclined to do more experimental based research versus theoretical.

Student majors and plans to stay in the major.

Summary: Nine respondents indicated if they were STEM majors and if they planned to stay in their major. All were STEM majors, specifically astronomy and physics double majors, and all planned to stay in their majors.

Do you have a STEM major?

	Pe	ercent	Count
STEM Major		100%	9

Do you plan to stay in this STEM major?

	Percent	Count	
Plan to stay in major	100%	9	

Course impact on decision to remain in STEM majors

Summary: Five respondents indicated that the course did impact their decision to remain in their major, with four reporting increased interest in astronomy/physics. One noted that he/she lost interest due to experiencing how research is conducted in the field. Four reported the course did not impact their decision to stay in their major and indicated that they were already committed to their education pathways.

			Percent	Count
Yes			55.6%	5
Νο			44.4%	4
Yes, impacted decision to stay in major.	I	No, did not impact decisi	on to stay in major	
 Encouraged me to stay in I am more confident I want to stay in astronomy after improvinskills. This course caused me to lose interest in Astronomy and had sooner I probably would have dropped astronomy as a major. me feel that Astronomers aren't really interested in physics budiscovering new things as quickly as possible even if they don't things they are discovering. This bothered me. It showed me how interesting research in these fields is. Explored more things that peak my interest. 	my research aken this course nis course made nore so in iderstand the	 I am set in what I wan it did not effect my de It did not change my de I'm graduating this sen I was an admitted Ph.I stay with astronomy r on going onto the the point out some aspect for the theory track. O found certain common barrier to doing good 	t to do, and this cour ecision lecision to continue w nester. D. student by time I fin regardless of this cour ory/ computation trac ts of observational ast Df course, observation n problems especially science.	se did not make me doubt that. Thus, with my major. nished this class so I knew I wanted to rse. I will say that I originally intended ck of astronomy, and this class did cronomy which confirmed my desire n is vital and I'm happy to learn it. I just with data bases to be an annoying

Has your participation in this course impacted your decision to remain in your major or change your major?

Respondents' interest in pursuing graduate education

Summary: All respondents were interested in pursuing graduate education in astronomy, astrophysics, or physics.

Are you interested in pursuing graduate school?

	Percent	Count	
Yes	100%	9	

What degree and field?

- Astronomy and or planetary science, I want to get my PhD
- Astrophysics
- Astronomy
- PhD, astronomy
- Undecided. astrophysics, biophysics, or machine learning
- Physics degree
- Physics/Astrophysics
- Ph.D. Astrophysical Sciences
- I hope to get my Phd in physics

Course impact on respondents' decision to attend graduate school

Summary: Six respondents indicated that the course impacted their decision to attend graduate school with many noting the exposure to the research process inspired them to pursue graduate school. Three reported no impact on their graduate school plans as they were planning on attending or had already been admitted.

Has participating in this course affected your interest in pursuing graduate school?

	 	 Percent	Count	
Yes		66.7%	6	
Νο		33.3%	3	

In what ways?

- Focus on research in the class has shown that I truly enjoy research, and that I can do it and thus I can be successful in grad school
- It confirmed that I want to do research, specifically computational research.
- I am more likely to apply to graduate schools.
- I'm interested in many different topics. For my research project we used machine learning. I realized that I can apply machine learning to many different fields, so it has increased my interest in pursuing graduate school for machine learning.
- Gave me an introduction to how research may be conducted in grad school.
- I realize getting into grad school will be harder than I expected.

Why not?

- I was planning to go to graduate school before taking the course.
- I was already pursuing graduate school
- I was an admitted Ph.D. student midway through this course and the course did not change my mind. It was positive in that it taught me interesting problems to pursue in graduate school.

Respondents' suggestions to improve the course

Summary: Respondents main suggestions to improve the course were on altering the content and changing the structure. Some felt the research proposal process could have benefited from further assistance, such as separating the initial proposal process into two parts with feedback in between.

Content

- There was not a heavy focus on statistics, and I felt that I did not learn or apply any statistics to my project.
- The work load for the course was heavier than that of other 3 credit courses.
- The plot summaries are good until we pick a research project. After, the plot summaries (and reading the papers necessary to create the plot summaries) took significant time away from my research project and I think I could have made more progress if they weren't assigned.

Structure

- Break out writing the initial proposal into two steps. An outline or the over all question where we get feedback, and then the proposal.
- More assistance with the project proposals at the beginning of the semester to help formulate proposals that are possible.
- Have a professor who is well versed in coding and creating plots themselves. Also, allow the use of other coding languages besides Python. Less guest speakers and more time actually doing hands on work, such as learning how to make different kinds of plots or being taught new types of statistics. Also, having more time to do major projects would have been good. Our first major project was very rushed.

Other

- The main piece I don't understand is how one individual with an area of expertise in one aspect of astronomy is supposed to be able to jump into any other subdiscipline in a matter of a week. If each project were advised by a different professor with their own grad students and postdocs to help, then I'd think it's a great idea. But asking one professor to advise 3 widely different subject areas is a lot to ask of that professor, and there's an especially large pressure placed on the TA who has to learn all of the background and tools to help the students.
- I realize since this is the first year this course was offered that it was kind of a learning curve, but all of us learned better ways to run the class for next time and I believe it will just continue to get better.

Respondents' demographics

Summary: Nine respondents provided background information. A majority of respondents were female and not first generation students. All were white/caucasian.

Gender	Percent	Count	
Male	33.3%	3	
Female	66.7%	6	
Race/Ethnicity			
White or Caucasian	100%	9	
First generation student status			
Yes	22.2%	2	
Νο	77.8%	7	

Recommendations

- Focus the course less on breadth of information and go more in-depth on each topic. By spending more time on each topic, students may be better able to understand the information, especially given that some may not have backgrounds in astronomy or statistics. Consider if it is feasible to spend more time on proposal development than on plot summaries.
- Some students felt that their questions were not adequately addressed or they were still confused about topics. Teaching or graduate assistants, if available, could host sessions or additional office hours where they answer student questions pertaining to course topics.



Response Statistics for ASTRO 350

Summary: Eight of the nine (89%) course participants completed the course evaluation.



Course logistics

Summary: Most respondents (7-8) agreed that the course raised challenging questions and stimulated deeper thinking about the subject. They also agreed that the instructor presented lecture information well and had a strong command of the content. Only two respondents agreed that having special events enhanced the learning experience, which could potentially be due to the course not including special events this semester. Only one respondent agreed that the instructor handled student questions and concerns well.

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The course raised challenging questions.

The use of real world data was valuable to my learning. Instructor had a strong command of the subject matter. Lecture information was presented in a logical, step-by-step order. Instructor demonstrated enthusiasm for the subject matter. The course stimulated interest and deeper thinking about the subject. The opportunity to collect my own data was useful to my learning. Instructor was available to provide assistance during office hours. Having special events, such as field trips, enhanced my learning experience. Instructor could identify and address student concerns about the material. Instructor handled student questions well.

Jisagree	Neither agi	ree/disagree	e Agre	e			
			8				
			8				
			8				
				7			
				7			
				7			
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	3				5		
			5			2	
	4				3		
		6					
	•			_		-	
I	2	3	4	5	6	7	

Course outcomes

Summary: Respondents (6-8) generally agreed that the course increased their knowledge of course objectives, especially understanding of the research process, image processing, photometry, computer programming languages, and of astronomical software. Three out of eight respondents agreed that the course increased their interest in astronomy research and in becoming an astronomer.

Disag	ree	Neit	ner agre	ee/disagr	ee	Agree					
					8						
						7					
						7					
						7					
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	2										
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0	I		2	3	4		5		6	7	£

Increased my understanding of the research process in astronomy/astrophysics.

Increased my understanding of UNIX.

Increased my ability to program with Python.

Increased my understanding of image processing.

Increased my ability to use astronomical software.

Increased my understanding of photometry.

Increased my ability to reduce and analyze data to produce new astrophysical measurements.

Increased my overall knowledge of astronomy/astrophysics

Increased my knowledge of basic statistics (probability distributions and error analysis).

Increased my ability to process data using student-developed codes.

Increased my ability to produce written and oral reports on my work.

Increased my excitement and passion for astronomy/astrophysics.

Increased my interest in astronomy/astrophysics research.

Increased my interest in becoming an astronomer. Increased my knowledge of basic astronomy concepts and definitions.

Increased my ability to operate research telescopes and other instruments.

Course impact on respondents' understanding of the research process

Summary: Four students noted that the course gave them a better idea of the astronomy research process, including the importance of statistics and data in research. Three students found the pace too fast or the material very difficult given their backgrounds. And, one decided not to pursue an astronomy career.

Course improved understanding of astronomy research and careers

- In this course, I have come to realize just how intricate astronomical data processing is, and I have gotten a snippet of the type of research that I will be doing as a professional astronomer.
- It's not as out of the reach as I expected it to be.
- This course shed a lot of light on the research process. Apparently, I was ignorant to what astronomers actually do, because this class was not what I was expecting. While I did learn a lot about the research process, this course mostly taught me that this isn't something that I want to do as a profession.

Specific aspects of the research process: importance of statistics

· I learned the importance of statistics when making measurements for data.

Course moved too quickly to give students strong research skills given their backgrounds

- The course material is amazing, there is just far too much too quick. This is an astronomy 350 course, not a graduate level course. I have taken grad level astronomy courses before at [name removed] and this class exceeded both the workload and the material expected to be retained. Not to mention, this class has much lower prerequisites.
- I am still pretty confused. I understand somewhat the process of getting data, data analysis, and processing it, but my skills are not to the level I wished to have achieved from not being able to be taught in a slower paced manner.
- I realize how difficult it actually is. For me, particularly, I found most of the advanced statistics concepts were quite daunting to handle, considering I haven't taken upper division statistics. I feel this course challenged me well and I learned alot from it, but if I had a strong previous statistics and programming background it would have been easier.

Course impact on respondents' interest in becoming an astronomer

Summary: Four respondents shared that the course increased their interest in becoming an astronomer by increasing their confidence and comfort with aspects of astronomy research, including programming and measuring data.

- No matter what, I love astronomy, probably more than anything life has to offer. It has always been what I am most passionate about and I would choose this career path over anything.
- I used to think programming was for nerds haha. But i realized how powerful of a tool it is and how rewarding it is when undertake a new discipline and get actual results from them. So this course has made me feel more comfortable about an aspect of astronomy that I used to think was dull and difficult.
- This course has increased my interests because measuring our own data made it more significant and satisfying.
- More confident in research

Course impact on respondents' interest in conducting research in astronomy or astrophysics

Summary: Five respondents explained the ways in which the course increased their interest in conducting research in astronomy or astrophysics. A few commented that they are inspired to explore some topics further, such as coding and observations techniques. Two commented that the course increased their confidence in conducting this type of research.

- This course makes me want to explore more coding aspects that relate to galaxy evolution research
- In this course, we didn't tackle the subjects of spectroscopy, spectropolarimeter, and other more advanced observational techniques. Even though photometry is
 difficult, I find it pretty cool, but I also want to expose myself to other techniques that weren't covered in this course. I want to apply what I learned to projects of my
 own
- In this course, as previously stated, I have learned a lot about how to process astronomical data and with the tools that I gained, I feel confident that I can conduct further research in the future pertaining to my own interests.
- More confident in research
- I now know how challenging this career really can be, but it hasn't stopped me from achieving those goals. To emphasize more, now I just want to commit more time to becoming skilled at astronomical techniques as much as possible since I do plan to aim for a Ph.D in Observational Astrophysics one day. Dedication is key and I have an infinite amount of passion to drive it.

Student majors and plans to stay in the major.

Summary: All respondents were STEM majors, specifically astronomy majors. Six of the seven respondents who answered this question planned to stay in their STEM major. One respondent did not indicate whether they planned to stay in their STEM major.

What is your major?

	Percent	Count	
STEM Major	100%	8	

Do you plan to stay in this STEM major?

	Percent	Count	
Plan to stay in major	86%	6	
Do not plan to stay in major	14%	I	

Course impact on decision to remain in their majors

Summary: All eight respondents indicated that the course impacted their decision to remain in their major, with three reporting the course influenced this decision in positive ways. Two noted that they considered changing their majors because of the course, and one noted disillusionment with the process of astronomy. One did not specify the impact of the course.

Has your participation in this course impacted your decision to remain in your major or change your major?

	Percent	Count	
Yes, course impacted decision to remain in major or change major.	100%	8	

Yes, impacted decision to reconsider major
 If I had taken this course at my sophomore year I would have changed my major. However, since this is the last course I need for astronomy I can't.
The course is extremely difficult and time-consuming. Many hours of studying and
attending lectures are required to keep up with the workload demand, making it difficult for students' to succeed in their other courses in physics and math that
are also difficult and time-consuming. There is a strong inclination to major in physics.
• I learned that I don't actually like the process of the astronomy, but its results.
1

Respondents' interest in pursuing graduate education

Summary: Seven of the eight respondents were interested in pursuing graduate education, with six specifying their degree would be in astronomy, astrophysics, or physics. Three planned on pursuing a Ph.D., one a Masters, and the other two did not specify.

Are you interested in pursuing graduate school?

	Percent	Count
Yes	87.5%	7
Undecided	12.5%	I.

What degree and field?

- PhD in astronomy
- Ph.D in Observational Astrophysics
- Ph.d in Astrophysics with emphasis in cosmology and transient objects.
- Applied Mathematics or Physics
- Astronomy Physics Astrophysics
- Masters in astronomy, astrophysics, astrobiology, astrodynamics, or optical physics

Course impact on respondents' decision to attend graduate school

Summary: Three respondents indicated that the course impacted their decision to attend graduate school with two noting the exposure to the research process inspired them to pursue graduate school. Five reported the course had no impact on their graduate school plans, either because they were already planning on attending or because they had not decided to pursue graduate school in astronomy.

Has participating in this course affected your interest in pursuing graduate school?

Response	Percent Count
Yes	37.5% 3
Νο	87.5% 5
In what ways?	Why not?
 I have once again seen the tools that could help with graduate research. However, it is not possible to retain this information without access to my computer and many many notes. This course has negatively impacted my progress and gpa, which are important factors for pursuing a graduate degree. 	 Already planning to attend I always planned on attending graduate school and this course enhanced my coding abilities. I wanna pursue grad school regardless of this course. Regardless, I have always wanted to achieve a Ph.D knowing it is the level of knowledge I wish to acquire based off of the type of research I want to do in my career.
	 Undecided, or not planning to attend graduate school for astronomy Undecided before course I wouldn't pursue graduate school for astronomy.

Respondents' suggestions to improve the course

Summary: Respondents provided suggestions to improve the course. They suggested slowing down the pace of the course, adding more prerequires, and providing more examples in lectures. Some felt additional instruction in Python and other packages would be helpful.

Adjust pacing and difficulty

- Please tone it down. It was really difficult and at times felt impossible. We want to learn this, just at a sensible pace.
- The class needs to be more slower paced and not so synonymous to graduate work. Smaller step by step processes are needed in order for us all to absorb the material enough to
 become second nature before jumping into higher level projects. (This respondent added that he/she would like the instructor to answer questions more deeply and that he/she
 would appreciate if the instructor presented used a more supportive attitude when working with students.)

Present additional examples and material in class lectures

- Do more examples in lecture
- One thing that could have really helped was if the instructor covered more relevant material in lecture towards the beginning of the class. He started doing this towards the end though.

Provide more instruction in Python and other packages

• More in depth review of the course material, a step-by-step tutorial of each command used in Python, a manual containing information and how-to's on each package used in the course (i.e. numpy and scipy)

Add prerequisites

- The expectations and work load were far too much for this course. Given that this is only the first class astronomy majors have to take that requires coding skills, it was sort of a shock to try to adapt to how everything is supposed to be done. The work that we had was recycled assignments and projects from the graduate level version of the course that is taught here.
- There should be some type of pre-requisite and I would recommend this course for seniors
- There are no programming prerequisites to take this course, and many students have absolutely no experience with programming. Assignments and expectations could be more reasonable for those who struggle with the material.

Change course structure

Offer this as a two part course to:

I. Cover other techniques and concepts.

2. First part should be easier and teach programming a little more so everyone is comfortable going into the second part, which would be more focused on astronomy.

Most useful/best aspects of the course

Summary: Respondents explained the most useful or the best aspects of the course. They appreciated the immersion into computer programs and techniques necessary for coding and research analysis in Astronomy and Astrophysics, with five respondents specifically mentioning Python. Several students identified the rigor of the course and its emphasis on skill building as most useful.

Course challenged students to work together and to work hard

• The level of difficulty pushed students to work hard independently as well as collaboratively to fill massive gaps in knowledge necessary for the assignments, which were not addressed effectively enough by the professor.

Course emphasis on skill building instead of exams

- There were no exams. The student learns just how familiar with programming an astronomer must be in order to work in the field.
- Scientific paper writing.

Immersion into specific programming languages, computer platforms, and software

- Learning Python because it defiantly is the dominate language of modern day for Astronomy/Astrophysics research.
- The immerse information into Python coding, I now know how to use UNIX thoroughly and can perform basic data analysis.
- Python, Astronomy techniques
- github and jupyter notebook were cloud-based software that finally allowed me to bridge the gap between my experience coding in Fortran and moving onto the more modern language python.
- · Learning how to de-trend images, learning LaTeX, and increasing my knowledge in Python
- · Aperture photometry, image processing, modeling data, and exposing me to programming

Respondents' demographics

Summary: All eight respondents provided background information. Respondents were mostly male; from a variety of racial/ethnic backgrounds including Hispanic/Latino, White/Caucasian, and Asian; and not first generation students.

Gender	Percent	Count
Male	75%	6
Female	12.5%	I
Other	12.5%	I
Race/Ethnicity		
Asian	12.5%	I
Hispanic or Latino	37.5%	3
White or Caucasian	37.5%	3
Multiracial	12.5%	I
First generation student status		
First-generation student	25%	2
Not first-generation student	75%	6

Recommendations

- Consider restructuring course sequence so that students enroll in programming/introductory courses before taking this course.
- Consider focusing more time on each course topic. Students would appreciate more instruction in statistics and programming (Python and other packages). However, if prerequisites that cover these topics are required, students may need less instruction in this course.
- Provide additional resources for students struggling with pace and content of course materials, including coaching sessions and drop-in tutoring.
- Encourage students to organize study groups.
- Experiment with different strategies for responding to students' questions.



Response Statistics for ASTRO 6005

Summary: Six of the eight (75%) course participants completed the survey.



Course logistics

Summary: Six respondents agreed that the course was engaging and experiences in the course were valuable to their learning. They also agreed that the instructor was knowledgeable and enthusiastic about the content and handled questions well.

5

Neither agree/disagree Disagree Agree Lecture information was presented in a logical, step-by-step order. 6 The course raised challenging questions. 6 Having special events, such as field trips, enhanced my learning experience. 6 The use of real world data was valuable to my learning. 6 The opportunity to collect my own data was useful to my learning. 6 Instructor handled student questions well. 6 Instructor could identify and address student concerns about the material. 6 Instructor was available to provide assistance during office hours. 6 Instructor demonstrated enthusiasm for the subject matter. 6 Instructor had a strong command of the subject matter. 6 The course stimulated interest and deeper thinking about the subject. 5 0 2 3 4

Course outcomes

Summary: Respondents agreed that the course increased their knowledge of course objectives, especially understanding of the research process and techniques including telescope observations, photometry, and data analysis. A majority (5 of 6) agreed that the course increased both their interest in astronomy research and careers, and their excitement and passion for astronomy/astrophysics.



Course impact on respondents' understanding of the research process

Summary: Six respondents commented that the course gave them a better idea of astronomy research, including the importance of data and image reduction in that research. They appreciated the step-by-step guidance through the research and analysis process.

Course guided students step-by-step through the research and data analysis process

- Data gained from observations need to go through reductions in order to be useful in analysis. By learning this, good image reduction and photometry are just as important as being able to get good observation data.
- This course show step by step and finally get the big picture of what we are doing during the class.
- Follow step by step to learn how to reduce the data.
- This course gives a experience from imaging, reduction, and analysis of my own data. So it show the basic process of research. We also have a chance to process some archive data, which give another aspect of research approach.

Course allowed students to operate equipment and use specific methods

- Actual operation
- Improving my research by IRAF

Course impact on respondents' interest in becoming an astronomer

Summary: Respondents noted that being able to manipulate their own data in the course gave them a sense of accomplishment and generated excitement about astronomy, which increased their confidence and helped them to build broad skill sets.

Excitement and confidence built from working with own data

- It's very exciting for me to have my own data analysis and ultimately prove consistent with previous work. And it gives a positive feedback for my interest in becoming an astronomer.
- It is interesting to reduce the data which get by ourselves. After seeing the result of our data is similar to the theoretical one, it is so accomplishment.
- · resolute problem make me more confidence.

Immersion into broad skill set and practical activities of astronomers was meaningful

- To be an astronomer, you need to have a broad skill set: from understanding the Physics, to doing computer programming to further analyze what we know. This
 made it more interesting to become an astronomer, as this shows that not everything can be done by reading and accepting what is read, but also immersing into
 the data itself
- A good start to exercise and shows what astronomer do.

Course impact on respondents' interest in conducting research in astronomy or astrophysics

Summary: Four respondents indicated that the course gave them experience with specific research techniques and broadened their perspectives on research in astronomy and astrophysics. One respondent commented on the challenges of using IRAF software.

- The course involved data reduction and analysis by observing objects and utilizing programs. For someone who barely used programming before, it opens a new facet to fully grasp the nature of astronomy and astrophysics.
- This course give me another point of view or another example to start a research.
- Maybe I can get some data and reduce to compare with my simulation result.
- Make me know how a principle of computer doing in image process.
- IRAF is difficult to use.

Course impact on future education and careers

Summary: All six respondents agreed that participating in this course affected their interest in pursuing further studies or careers in a STEM related field, but they did not comment further. Three of six agreed that they planned to enroll in a PhD program in astronomy/astrophysics.

		Percent	Count	
Yes		50%	3	
Νο		16.7%	I	
Undecided		33.3%	2	

Do you plan to enroll in a PhD program in astronomy/astrophysics?

Respondents' suggestions to improve the course

Summary: Two respondents provided suggestions to improve the course. One mentioned challenges related to a limited coding background, and the other suggested offering additional IRAF references to students.

- I've got difficulty during following several step that required coding skill. That because my lack training in coding. For me, I have to give more time in coding to know what actually I need and transform it into coding.
- It's better for students to have more to reference from during the IRAF part of this course. For instance, some command lines could be given to student in paper rather than noting down everything during the class. In this way, student may be more focus on the process.

Respondents' demographics

Summary: All six respondents provided background information. Most respondents were male and all were Asian. Four students listed "Astronomy" as their field of study, one listed "Open Cluster," and one listed "Kepler."

Gender	Percent	Count	
Male	66.7%	4	
Female	33.3%	2	
Race/Ethnicity			
Asian	100%	6	
Current degree of study			
M.S.	100%	6	

Recommendations

- Consider distributing additional handouts about IRAF commands or programming languages so that students can focus on course concepts presented during classes and reference the handouts when they need additional information or background.
- Continue activities and assignments that allow students to manipulate their own data, then compare them to openly available data. Respondents found these activities highly engaging and helpful for building their confidence.