SmartStart Evaluation SmartBrief

NSF Partnerships for International Research and Education (PIRE)

California Institute of Technology

2016-17 Quarter 3: September 1 – December 31, 2016

What is the GROWTH PIRE project?

In 2015, the California Institute of Technology received funding for a Partnerships for International Research and Education (PIRE) grant from the National Science Foundation (NSF) for the Global Relay of Observatories Watching Transients Happen (GROWTH) project. GROWTH is an international scientific collaborative project in astronomy, studying the physics of fast-changing events in the cosmos like supernovae, neutron stars or black hole mergers, and near-earth asteroids. GROWTH is led by Caltech and has partnered with thirteen universities and research institutions (six in the USA and seven across the world in India, Sweden, Taiwan, Japan, Israel and Germany). The intention of this project is to continuously observe and gather data of cosmic transient events in the first 24-hours after detection, before many of them fade away in intensity below the sensitivity of telescopes. Project activities are conducted among undergraduate students, graduate students, postdocs, partner institution faculty, and researchers. This report presents formative (process) feedback on undergraduate GROWTH internships, GROWTH courses, and a Social Network Analysis. Key findings and recommendations are presented within each section of the report.

Project Goals

Goal 1: Knowledge and Research - Advance knowledge and research in identified areas of astrophysics.

Goal 2: Education and Workforce Development - Contribute to education, training and development of the STEM workforce

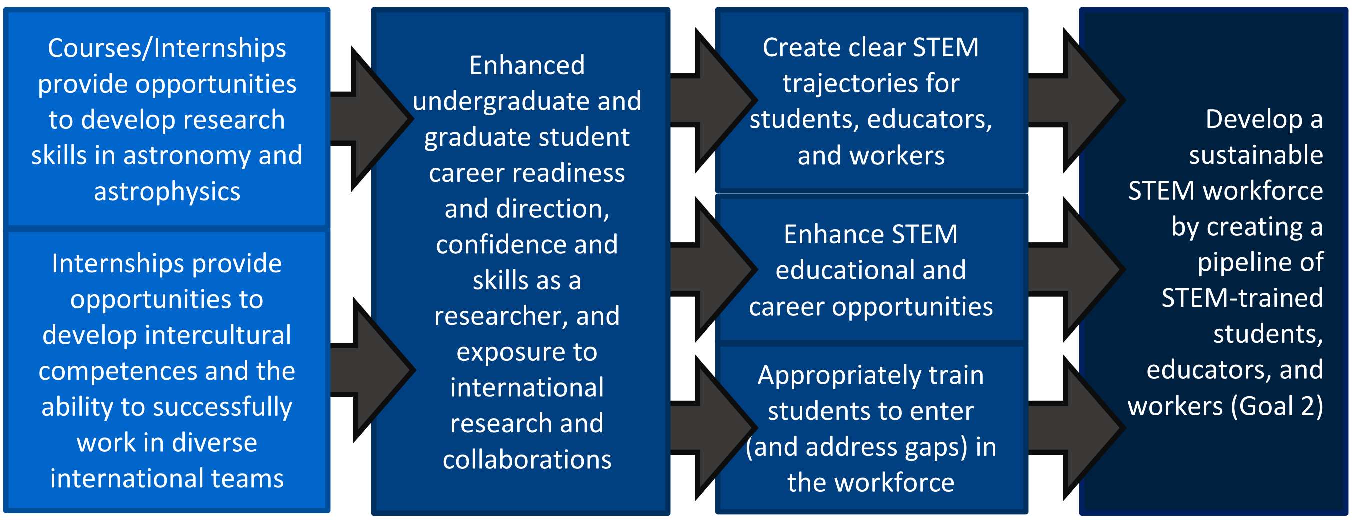
Goal 3: Capacity Building (Partnerships and Sustainability)- Create a strong collaborative network of scientists and facilities that catalyzes educational and scientific achievements in astronomy and astrophysics.

Evaluation Brief Content

Evaluation Overview

The current report presents findings from two activities: GROWTH undergraduate internships and GROWTH Fall 2016 courses. A Social Network Analysis (SNA) on project collaborations was also conducted and is presented in the report. This evaluation provides feedback on activity implementation and should be used to revise future iterations of these activities. For all activities evaluated and presented in this report, the evaluator utilized surveys as the primary data collection method and analyzed both quantitative and qualitative data. The activity sections include an overview of the activity, graphics that display ratings of components and growth in objective areas, participant comments, and key findings and recommendations. Three social network diagrams are included in this report. They should be used to understand connections between participants as well as in project planning.

The internships and courses both contribute to Goal 2, the education and workforce development goal, of the project. How these activities contribute to this goal area is detailed in the diagram below.



Assessment development

Assessment tools were developed collaboratively by SmartStart evaluators and project or activity leads. The following assessment tools were developed and utilized for the activities/components reported in this evaluation brief:

- GROWTH Undergraduate Internship evaluation form
- GROWTH Course evaluation forms (AY 122a, ASTR 310, ASTR 680)
- GROWTH social network survey

Data collection and analysis

Surveys were administered through online platforms (internships, ASTR 680, SNA) and hardcopy (AY 122 and ASTR 310). All quantitative results were analyzed with Excel and SPSS using means and response frequencies, and qualitative data were coded for themes. The social network data were analyzed through the network analysis software, Gephi.

Upcoming project activities that will be evaluated

- GROWTH participant publications (Spring 2017)
- GROWTH courses (Spring 2017)
- GROWTH Social Network Analysis (Summer 2017)
- GROWTH graduate and undergraduate internships (Summer 2017)

GROWTH Undergraduate Internships

November 2015 – August 2016 **5 countries** **5 participants**

Program overview

GROWTH offers international internships for undergraduate students to further their research knowledge and skills by collaborating with GROWTH project members in a new region. Student internships took place between November 2015 and August 2016, with the average internship lasting eight weeks. A total of five students participated in the internship program. All participants completed the surveys, however one only partially completed the survey.

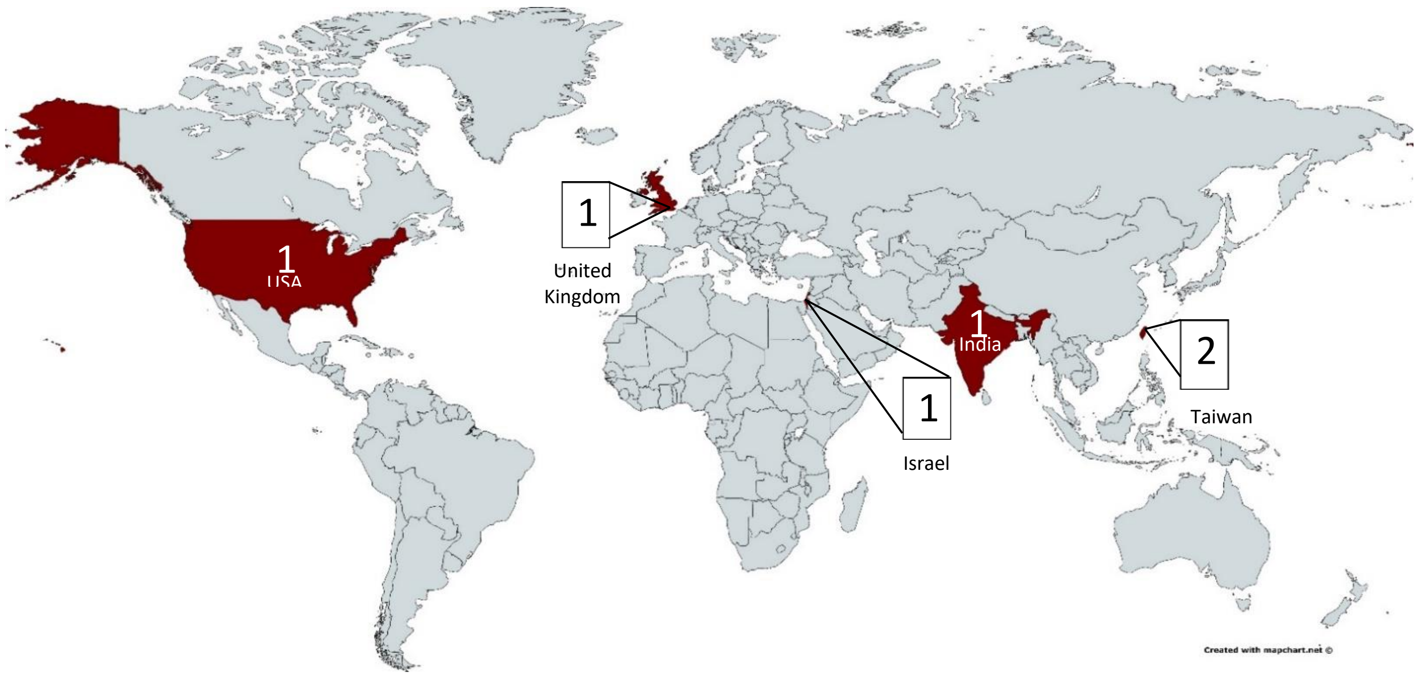
GROWTH internships objectives are to provide:

- Opportunities for undergraduate students to develop research skills in astronomy and astrophysics
- Opportunities for undergraduate students to develop intercultural competencies and the ability to successfully work in diverse international teams

Undergraduate internship locations

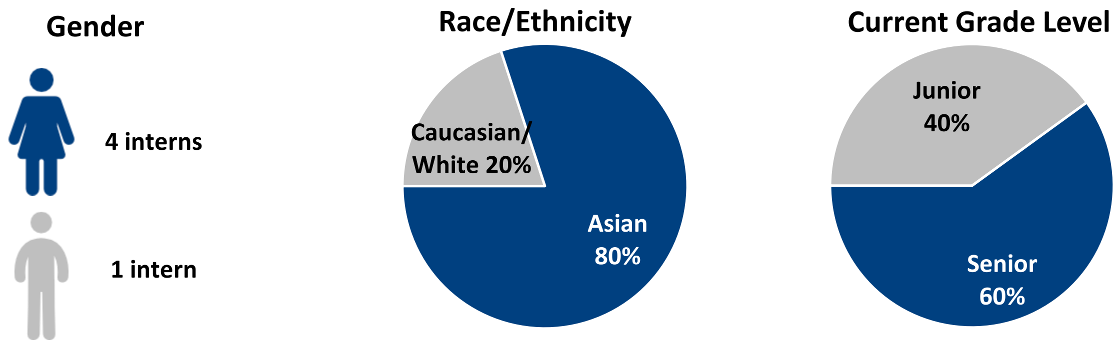
The undergraduate interns were hosted by five partner institutions. The following table shows the home institution for each student, institution(s) where they interned, and length of the internship. The map below displays the locations of the student internships. It should be noted that Student 4 split his/her internship time between two nations, so both are included in the map, however, the survey responses were only from the perspective of going abroad.

Student	Home institution	Visiting institution	Length of internship
Student 1	IUCAA, India	National Central University, Taiwan	4.5 weeks
Student 2	San Diego State University, USA	Weizmann Institute of Science, Israel	8 weeks
Student 3	University of Maryland, USA	National Central University, Taiwan	8.5 weeks
Student 4	Pomona College, USA	IUCAA, India and Pomona College, USA	9 weeks
Student 5	Caltech, USA	Liverpool John Moores University, UK	10 weeks



Demographics of internship participants

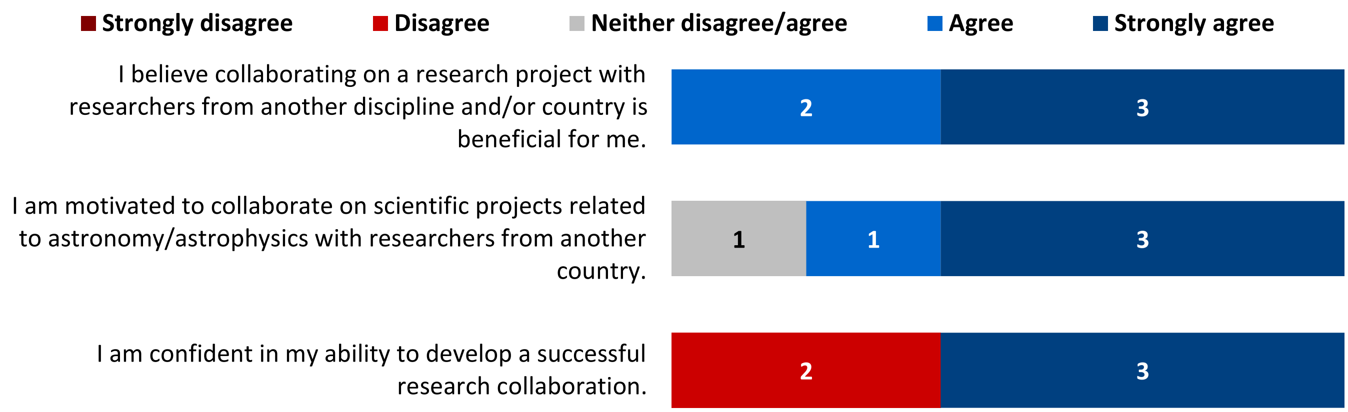
The demographics of the students who participated in the internships (n=5) are as follows: four of the interns were female, four were Asian, and three were college seniors.



Impact of internship experience

Collaboration capacity

Participants (n = 5) assessed the impact of the internship on their collaboration capacity through agreeing with statements relating to beliefs, confidence, and motivation around collaboration on a 5-point Likert scale from 1 = *strongly disagree* to 5 = *strongly agree*. Participants generally *agreed* or *strongly agreed* that they believe collaboration is beneficial and that they are motivated to collaborate. Two participants *disagreed* that they felt confident in their "ability to develop successful research collaboration[s] with astrophysics researchers from another country." Findings indicate that students may need more preparation before going abroad. Additionally, debriefing should occur when they return that focuses on continuing collaboration with international partners.

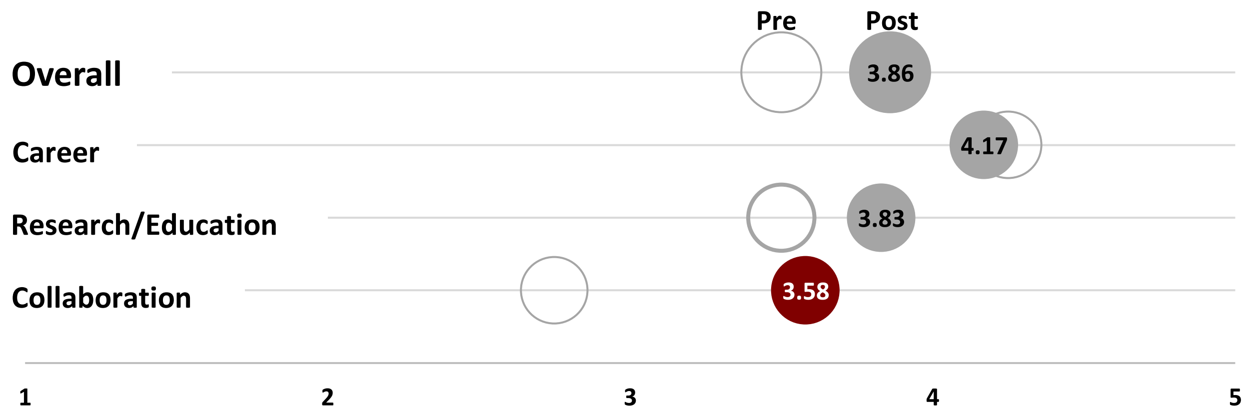


Research and career readiness

Participants (n = 4) rated their level of agreement in three impact areas about career readiness and direction:

- **Research and education**: three statements about exposure to research and preparation for graduate school
- **Collaboration**: three statements about strengthening/creating collaborations and enhancing understanding of collaboration
- **Careers**: three statements about interest in, knowledge of, and preparation for careers in astronomy and astrophysics

Participants retrospectively rated all nine items on a scale from 1-5, 1= *strongly disagree* and 5= *strongly agree.* Below the overall score for research and career readiness and collaboration is shown, as well as the composite scores for each area individually. Pre-scores are unfilled circles and post-scores are filled-in. The slight decrease in overall participants' career readiness is because one participant perceived a decrease in his/her "preparedness for an astronomy or astrophysics career." This could be because the student realized he/she knew less than they thought after taking the course. Participants perceived the greatest gains in their collaboration; however, collaboration had the lowest post-rating. The two students who *disagreed* that they were "confident in their ability to develop a successful research collaboration" (previous figure) also had lower ratings for these collaboration items, indicating students need help developing their connections. Results should be interpreted with caution given the small sample size.



Participants (n = 4) rated their level of agreement in four impact areas:

- **Increased confidence and skills as a researcher**: five statements about confidence in research, being challenged, and new ideas.
- **Enhanced exposure to international research and collaborations**: three statements about global awareness and approach to research.
- **Meaningfulness of internship**: two statements about their contributions and using skills.
- **Networking**: two statements about opportunities in networking.

Participants rated all 12 items on a scale from 1-5, 1= *strongly disagree* and 5= *strongly agree.* Overall, participants *agreed* with all statements, but had the most agreement that they had "increased confidence and skills as a researcher." Participants commented that the internship not only helped with their academic and career plans, but also increased their appreciation for the research and researchers in the field and gave them a broader perspective on potential career opportunities.

Perceived value of internship experience

The evaluator assessed the overall experience of the internship through examining if participants' (n = 4) needs and expectations had been met and if the participants perceived the internships as valuable.

- **100% of participants** indicated the internship **was valuable to their academic and professional growth.**
- **100% of participants** indicated the internship **was a rewarding experience**.
- **75% of participants** indicated the internship had **met their needs**.
- **50% of participants** indicated the internship had **met their expectations**.

Most satisfying aspects

Participants (n = 4) shared that the most satisfying aspects of their internship were research and work experience. Specifically, they learned to generate plots, and gained international and global awareness by working with astronomers from different cultures.

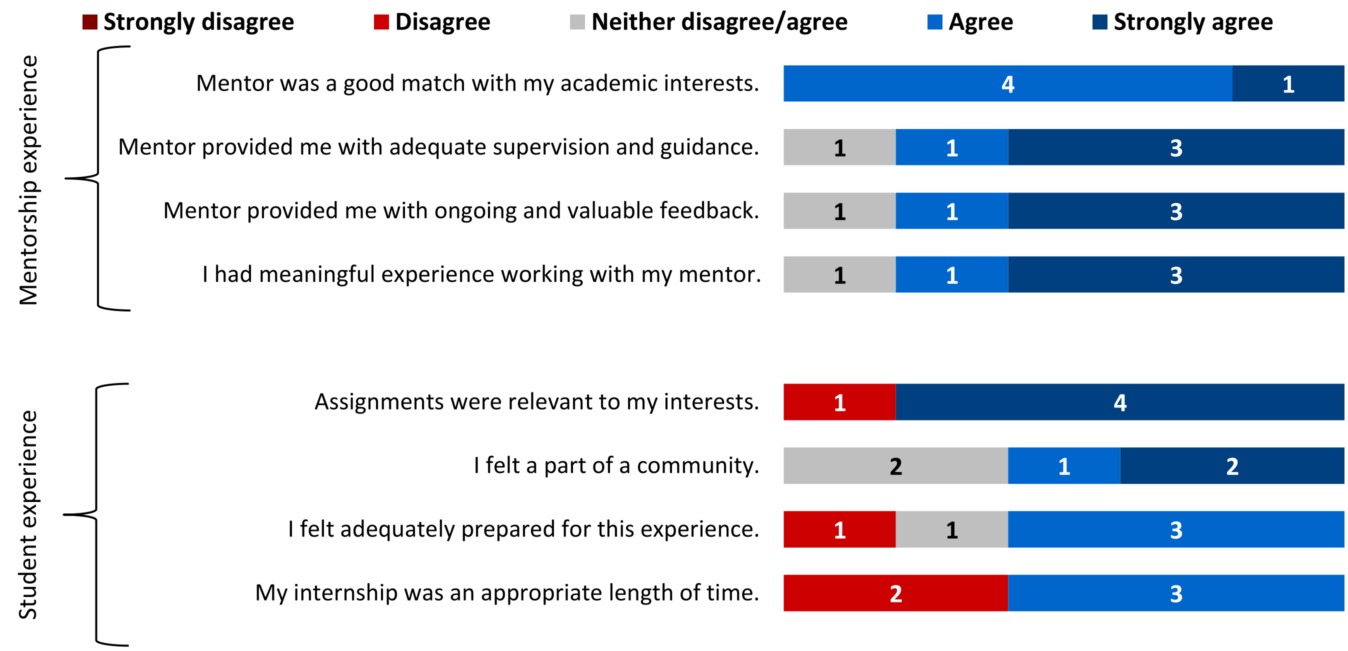
"The work I got to do was great, and I had a great mentor to help me through it. I think this has been one of the most influential summers of my life."

Least satisfying aspects

Participants (n = 4) shared that the least satisfying aspects of their internship were the work schedule and duration. Specifically, they noted the schedule was tiring and that they wanted more clarity around their work and assistance with the visa paperwork.

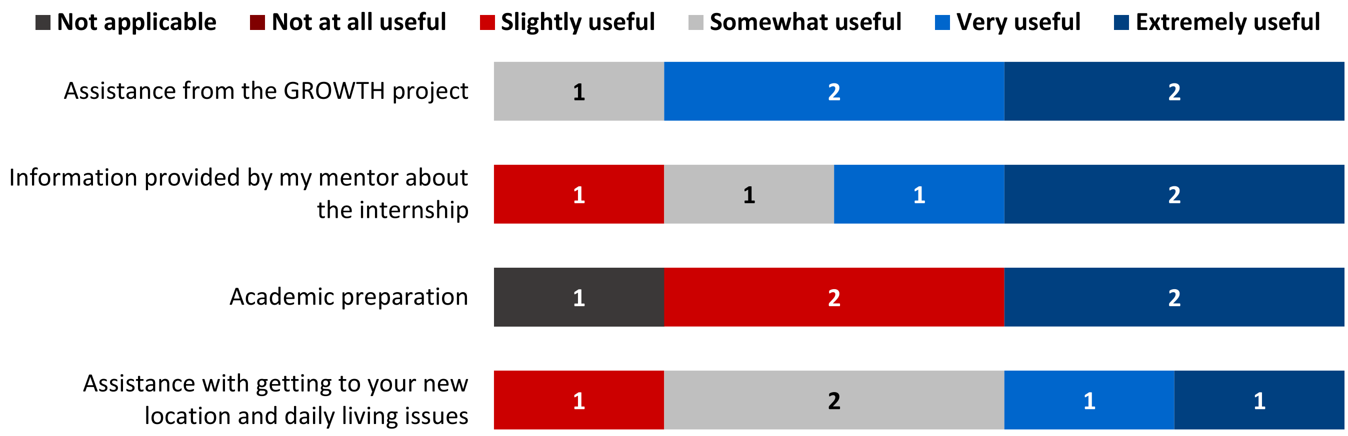
Internship logistics

Participants (n = 5) rated the overall logistics of the internship experience on a Likert scale ranging from 1-5, 1= *strongly disagree* and 5 = *strongly agree*. Logistics was divided into two subscales: student experience and mentorship experience. Overall participants *agreed* or *strongly agreed* that they had a positive experience with their mentor. All participants ag*reed* or *strongly agreed* "[their] mentor was a good match with [their] academic interests." At least three participants *agreed* or *strongly agreed* that they had a positive experience. Focus should be given to internship length, work assignments, in preparing students, and ensuring they feel a part of the community where they are interning.



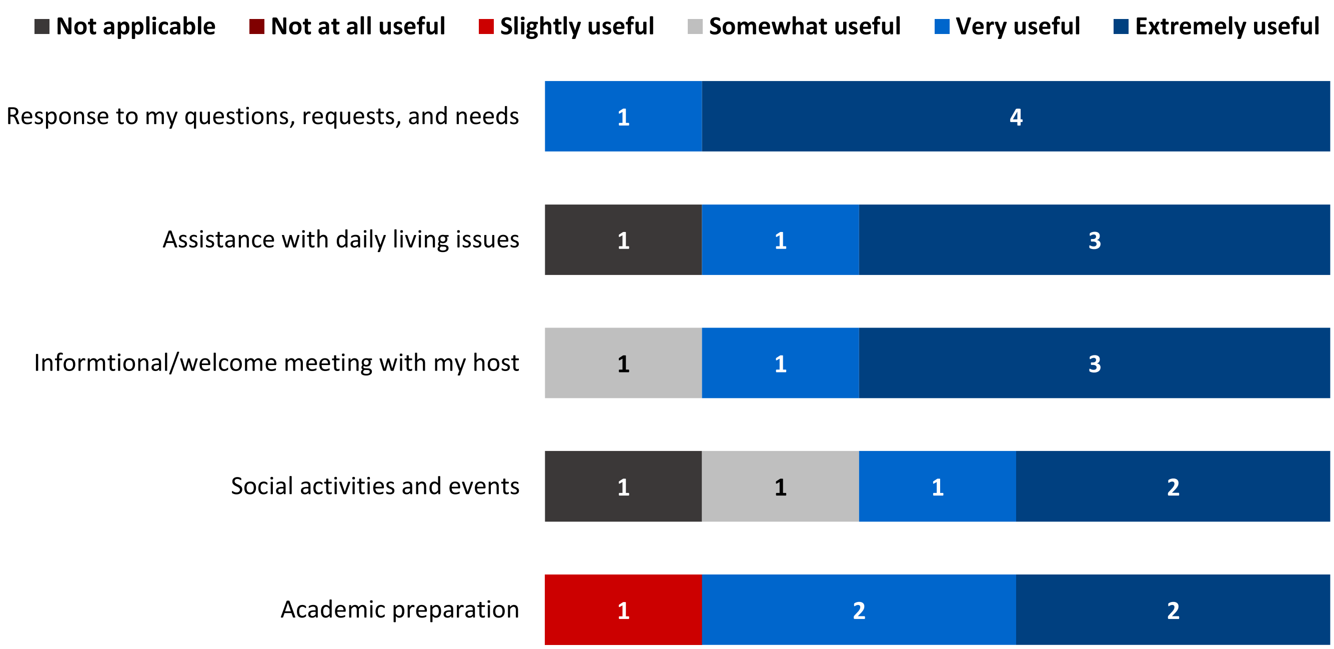
Support from home institution in preparation for internship

Participants (n = 5) rated the usefulness of the support they received in preparing for their time abroad on a 5-point Likert scale from 1 = *not at all useful* to 5 = *extremely useful*. While at least three participants rated the assistance and information they received as *very* or *extremely useful*, project leads should ensure that home institutions are academically preparing students and assisting them with daily living.



Support from visiting institution during internship

Participants (n = 5) rated the usefulness of the support services to their time abroad on a 5-point Likert scale from 1 = *not at all useful* to 5 = *extremely useful*. Most participants (4 – 5) rated the assistance from their visiting institutions as *very* or *extremely useful*. One participant indicated the academic preparation from their mentor was slightly useful.



Participants (n = 4) shared the **assistance they found helpful** and the **assistance that would have been helpful** from both their home and visiting institutions. Participants appreciated the assistance with housing and travel from their home institutions, but wished they had received more information about the visiting institution as well as the visa process. In regards to their visiting institutions, the participants were thankful for the individuals there, especially their mentors, but would have liked more hands-on experiences during their internships.

	Assistance they found helpful	Assistance that would have been helpful

Home institution	• Information on housing:
	  ○ List of housing options
	  ○ Mentor support
	• Air travel expenses
	• Visiting scientist web page
		• Logistics about visiting institution:
		  ○ Campus map in English
		  ○ Conversational phrases
		  ○ Transportation
		• Visa process

Visiting institution	• Individuals at visiting institutions:
	  ○ Especially mentors
		• More hands-on experience
		  ○ More trips to the telescope on locations

Key findings and recommendations

➢ **Help students make meaning out of their internships by assisting them in identifying ways to continue collaborative work, such as publication and presentation opportunities, and research projects at their home institution.**

- Participants reported low levels of agreement with statements about networking and sense of community, indicating more assistance is needed to foster these areas. Additionally, given that some internships were quite short, project coordinators may want to consider requiring a minimum length of time for internships, which may help students to gain a sense of community.
- Two students *disagreed* that they were confident in their ability to develop successful research collaborations with astrophysics researchers from another country.
- Although participants had the most growth, they had the lowest post-score rating for their collaboration readiness (strengthening/creating collaborations and enhancing understanding of collaboration).
- 100% of participants indicated the internship was valuable to their academic and professional growth.
- Participants were satisfied with the international and global awareness they gained.

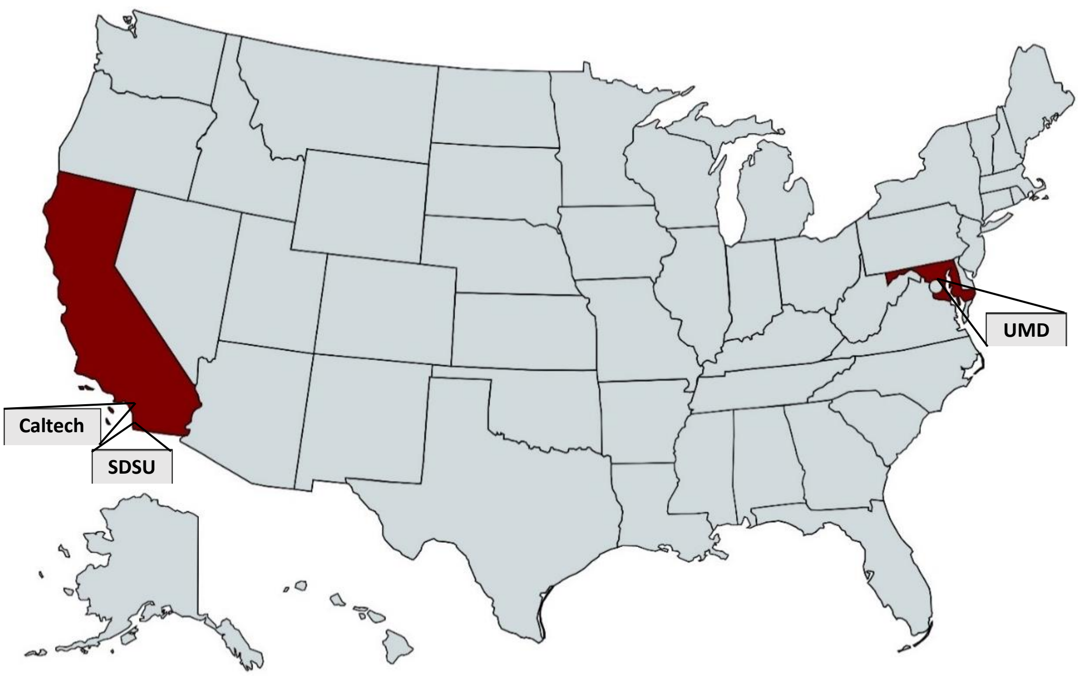
➢ **The internship program should continue to focus on student's preparation to go abroad, as well as the assignments and mentorship they are given.**

- Participants wanted more clarity around their work assignments. One student disagreed that the assignment was relevant to his/her interests.
- All participants *agreed* or *strongly agreed* that their mentors were "good matches with academic interests" and found the assistance from mentors helpful.
- Two participants *neither disagreed nor agreed* about "feeling part of a community" at their internship.
- Participants wanted more assistance with logistical information about the institution they visited and the visa process.

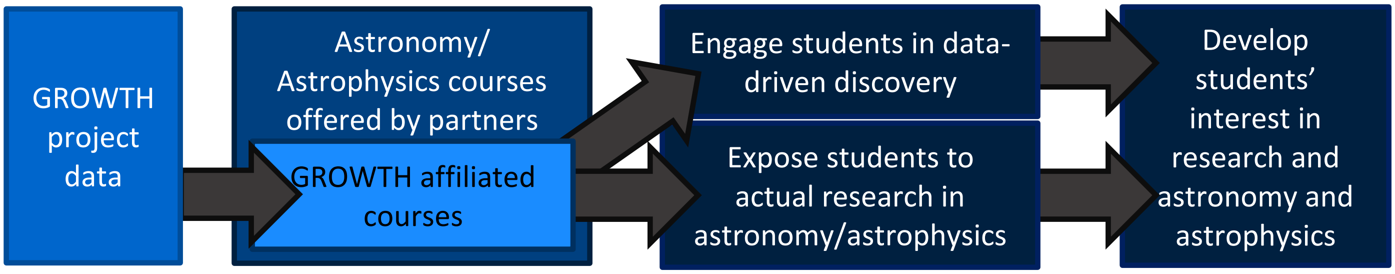
Fall 2016 GROWTH Course Evaluations

August – December 2016 | **3 partner institutions** | **41 participants**

In the Fall of 2016, three GROWTH partner institutions (University of Maryland, College Park [UMD], California Institute of Technology [Caltech], and San Diego State University [SDSU]) offered three undergraduate and graduate courses in astronomy and astrophysics.



The three courses incorporated data-driven research, wherein they utilized real-world data obtained through the GROWTH project. Students were given the chance to explore the project data on their own, while being offered support in the class setting. This hands-on approach was intended to expose students to research as well as stimulate a greater interest in astronomy and astrophysics. The diagram below displays how GROWTH courses impact student learning.



AY122a- Astronomical Measurements and Instrumentation

September – December 2016 **Caltech, CA, USA** **10 participants**

AY 122a: Astronomical Measurements and Instrumentation is a graduate course offered by the California Institute of Technology. This is an introductory course to basic instruments and measures used in astronomy and astrophysics, specifically infrared, optical, and ultraviolet techniques. The course utilized data from the Palomar Transient Factory for student learning.

Students will gain skills in…

- Telescope systems & optics and observations
- High Contrast Imaging and Adaptive Optics
- Spectroscopy and photometry
- Surveys, databases and machine learning
- Astronomical data analysis

Demographics of survey respondents

- Nine of the ten participants completed the course evaluation, for a 90% response rate.
- Four out of nine respondents were female. One did not specify his/her gender.
- Six of the nine respondents were Asian and three were Caucasian/White.
- One respondent was a first-generation college student.
- Eight respondents had STEM concentrations (four in astrophysics, two in physics, and two in astronomy). One respondent did not provide his/her major.

Key findings and recommendations

Most of the respondents mentioned the hands-on experience as the highlight of the course, and they ***strongly agreed*** **that "collecting their own data was useful to their learning."**

→ The course should continue to utilize GROWTH data and allow students to explore data on their own.

On average, almost all respondents (84%) reported *high* or *very high growth* in their knowledge and skills related to astronomy and astrophysics.

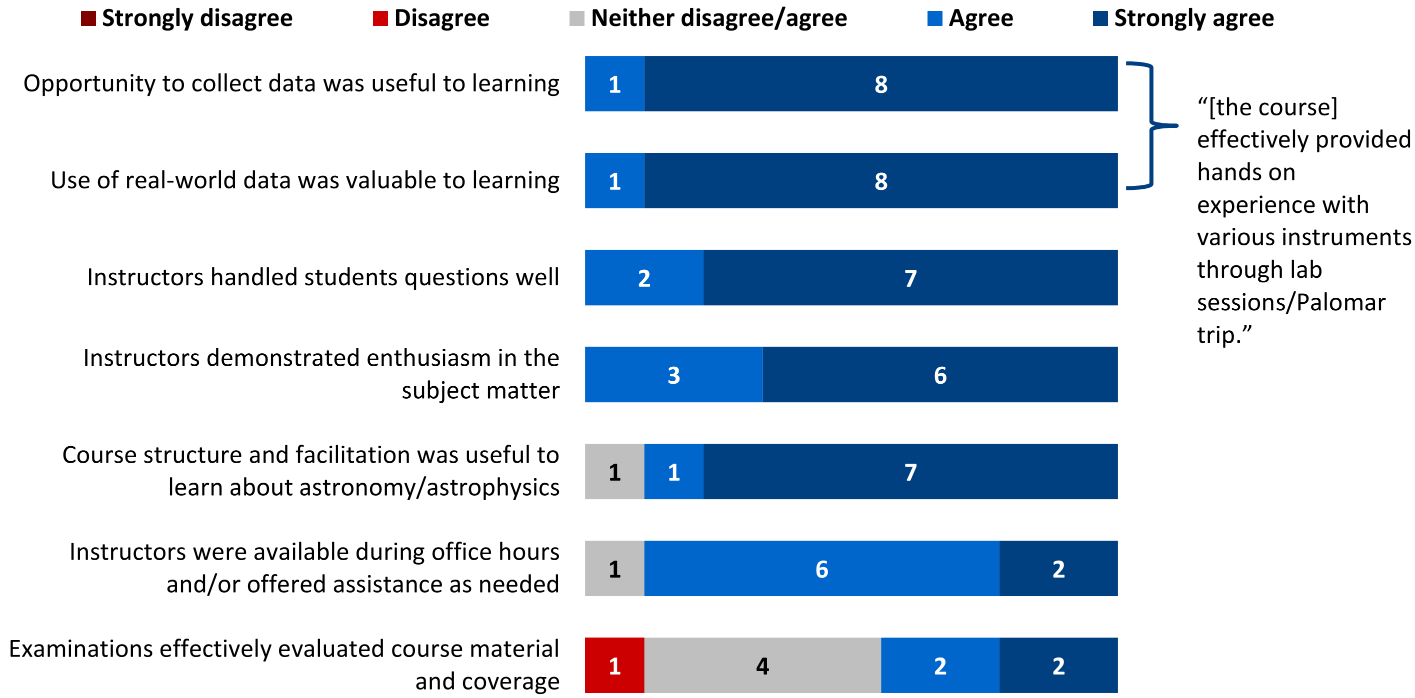
→ The course proved effective in increasing student knowledge. The course should utilize a similar format and methods in future sessions.

Seven out of nine respondents reported that the course increased their interest in pursuing further studies or a career in astronomy or astrophysics.

→ Consider utilizing aspects of this course, especially the hands-on learning aspects, for undergraduate education.

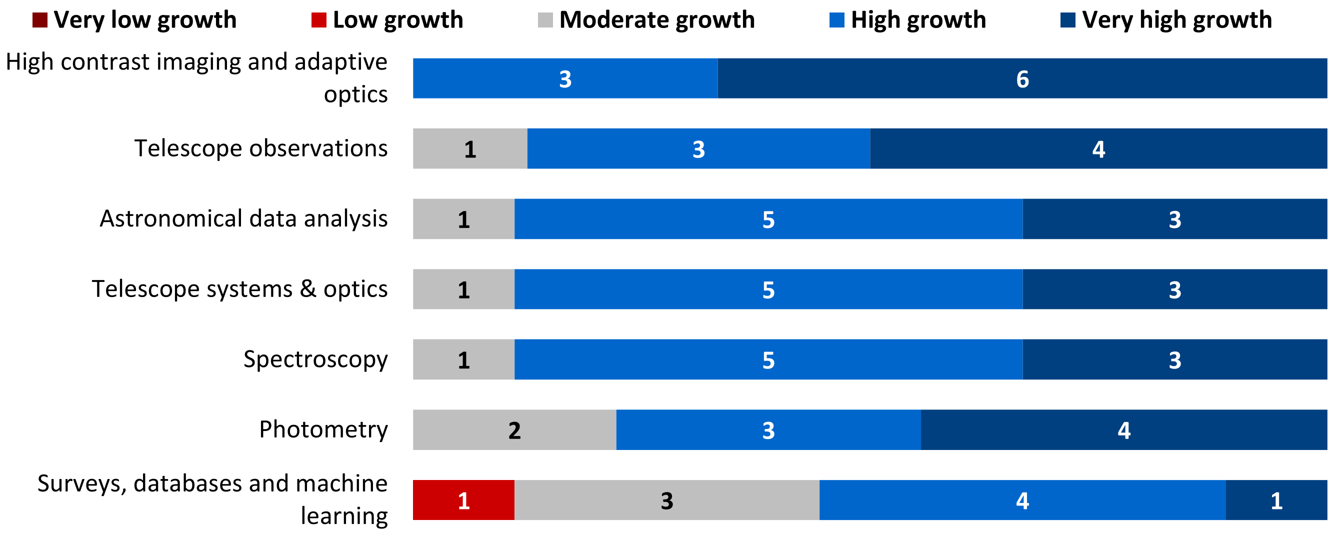
Course effectiveness

Respondents (n=9) rated their growth in eight areas on a scale from 1-5, 1 = *strongly disagree* and 5 = *strongly agree*. Eight out of nine respondents in the course *strongly agreed* that the "the opportunity to collect their own data was useful to their learning," and that "the use of real world data was valuable to their learning." One of the respondents *disagreed* that the "examinations effectively evaluated course material and coverage" and four *neither disagreed nor agreed*. The course instructor should focus on the alignment of material covered in the course with the exams.



Course outcomes

Respondents rated their growth in seven skill areas on a scale from 1-5, 1 = *very low growth* and 5 = *very high growth*. On average, almost all respondents (5 – 9) reported *high* or *very high growth* in all knowledge and skills related to astronomy and astrophysics. Instructors should focus on increasing student knowledge of "surveys, databases, and machine learning," as the participants reported the least growth in this skill area.



Influence on educational and career trajectories

Responses to five questions about educational and career trajectories indicated that:

- **8** respondents have a STEM focus and plan to stay in that area (1 did not respond).
- **7** respondents had an increased interest in pursuing further studies or a career in astronomy or astrophysics.
    - While the respondents gave varying reasons as to why the course increased their interest, several of the comments focused on the exposure to new topics or a new interest in a topic. Respondents' comments are shown below.

"It showed me many interesting topics about astronomy. But I think I'm still interested in physics problem and method."

"Already interested in astronomy."

"It gave a good introduction to observational astronomy."

"Encourage me to look into multiwavelength observations in my area of research."

"It gave a very practical viewpoint of astrophysics and observational techniques."

"Yes.. It's been one more step in convincing me I want to go into research."

"I gained a new appreciation for detector technology."

Comments and suggestions

Three respondents stated that the hands-on experience was the highlight of the course. One respondent found the course helpful in learning about various astronomical instruments and another respondent thought the course had the right balance of practical and theoretical perspectives. Respondents suggest expanding the length of the course and the number of lectures to allow more exposure to current research.

ASTR 310- Observational Astronomy

August – December 2016 University of Maryland, MD, USA 24 participants

ASTR 310: Observational Astronomy is an undergraduate course offered by the University of Maryland. This is an introductory course to optical observational techniques used in astronomy and astrophysics. The course featured the use of Palomar Transient Factory data, provided by the GROWTH project. Students were tasked to utilize the data to create a final project for the course.

Students will be able to…

- Understand and contribute effectively to all parts of the process of a "research project"
- Explain how typical optical telescopes and CCDs work.
- Compare capabilities of different optical systems of telescopes and CCDs.
- Understand and be able to utilize the fundamentals of modern observational photometry, astrometry, and spectroscopy.
- Understand the limitations of observational data and the data reduction process.
- Utilize large data sets to formulate a question that can be answered using the data set and manipulate/ search the data set to answer that question.
- Communicate research results effectively, in scientific papers and talks.
- Collaborate with other researchers productively.

Demographics of survey respondents

- Eighteen of the 24 participants completed the course evaluation, for a 75% response rate.
- Ten of the 18 respondents were male. One did not specify his/her gender.
- Fourteen of the 18 respondents were white/Caucasian, one was Asian, one was black/African American, one was multiracial, and one did not wish to specify.
- Nine of the respondents were sophomores, 6 were juniors, and 2 were seniors, 2 did not specify.
- One respondent was a first-generation college student.
- Seventeen of the respondents were in STEM majors (nine in astronomy and physics, seven in astronomy, and one in astronomy and geology).

Key findings and recommendations

All of the respondents *agreed* or *strongly agreed* that **"collecting their own data was useful to their learning" and "using real world data was valuable to their learning."**

Future iterations of the course should consider having students discover their own data, or continue to have students participate in data mining of existing data.

Most respondents reported at least *moderate growth* in their knowledge and skills related to astronomy, however, students reported less growth in their collaboration, presentation, and scientific paper writing skills.

Instructor should include guest speakers to introduce students to certain aspects of the field, or include more emphasis on oral presentation of work.

Fourteen out of eighteen respondents reported that the course had affected their interest in pursuing further studies or a career in astronomy or astrophysics.

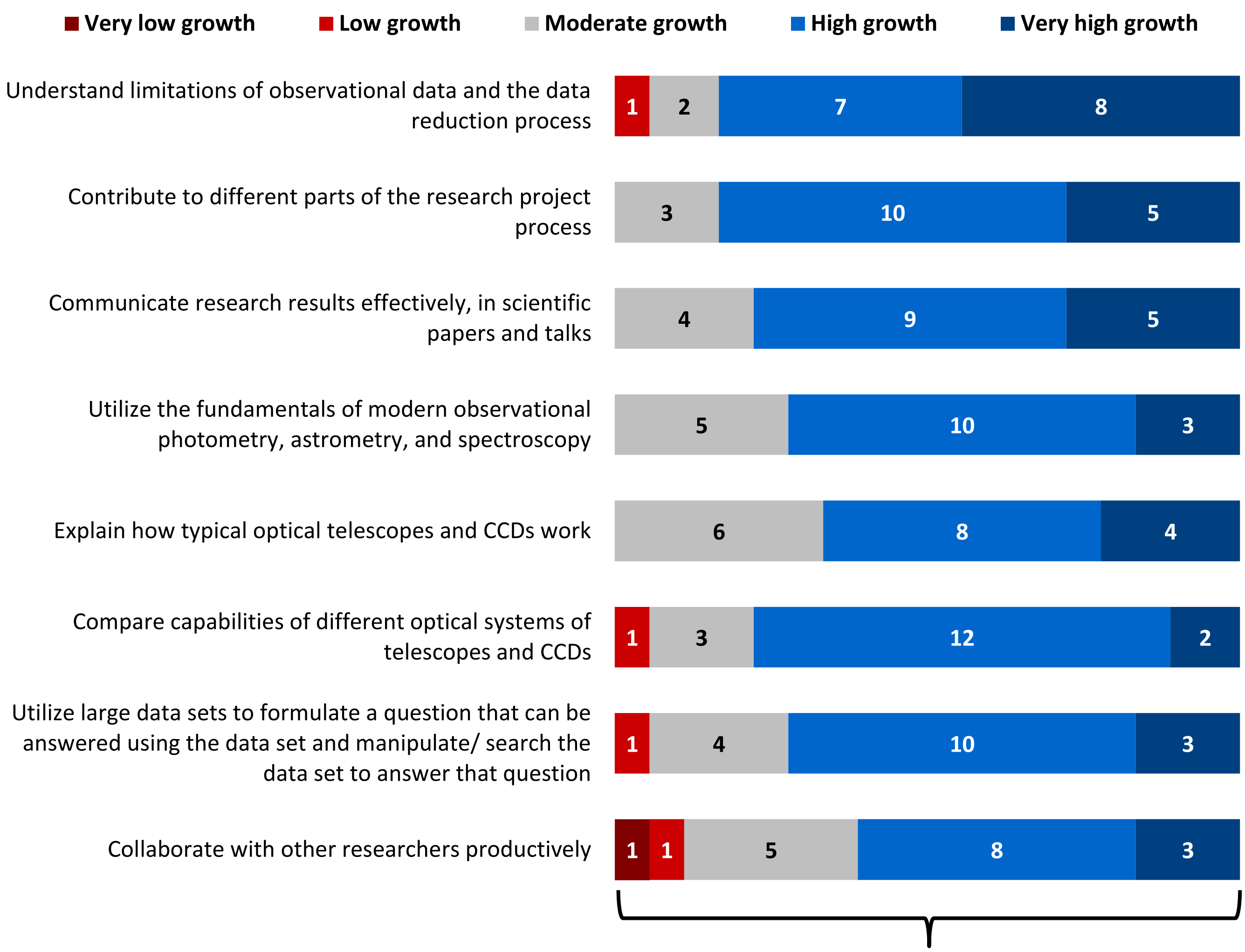
The course could be modified as a way to outreach to undeclared majors as a non-majors course.

Course effectiveness

Respondents rated their agreement with seven statements about course effectiveness on a scale from 1-5, 1 = *strongly disagree* and 5 = *strongly agree*. All respondents *agreed* or *strongly agreed* with all but two statements, which indicates that this course was well planned and implemented.

Course outcomes

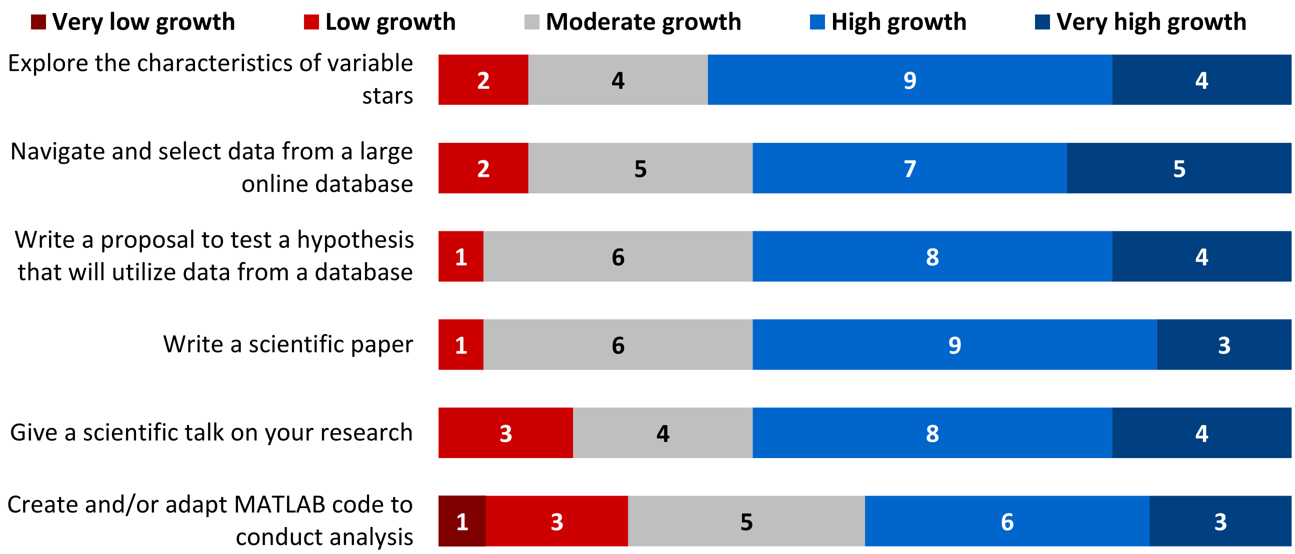
Respondents rated their growth in eight skill areas on a scale from 1-5, 1 = *very low growth* and 5 = *very high growth*. Overall, most respondents (11 - 15) reported *high* to *very high growth* in the course objective areas. Respondents reported the least amount of growth in their ability to "collaborate with other researchers productively." Given the importance of collaboration in the PIRE project, course instructors should consider not only bringing in outside professionals, but setting up visits with local researchers to allow students to develop their collaboration skills. It may also be outside the scope of this course for students to develop collaboration skills; therefore, this survey item may need to be revisited.



One respondent suggests "meeting people currently in the field, make connections with current researchers, or visit a larger observatory or other space-center career centers."

Outcomes related to course project

Participants rated their growth in six knowledge and ability areas on a scale from 1-5, 1 = *very low growth* and 5 = *very high growth.* Overall, at least half of the respondents (9 - 13) reported *high* to *very high growth* in their knowledge and skills. Four respondents reported *very low* and *low growth* in their ability to "create and/or adapt MATLAB code to conduct analysis," indicating an important area of focus for this course. This skill may be more advanced than the others, which is likely why respondents felt they made less growth in this area.



Influence on educational and career trajectories

Responses to five questions about educational and career trajectories indicated that:

- **14** respondents had an increased interest in pursuing further studies or a career in astronomy or astrophysics.
- **2** respondents were negatively affected by the course.
  - One respondent commented he/she was unsure if he/she want to do research anymore and the other student indicated the course showed him/her an aspect of astronomy he/she did not enjoy. Several respondents' comments are below.

"This course showed me truly what research in the field of astronomy meant. It gave me a better idea of what kind of research I would do as a grad student."

"Yes. The course gave me hands on research experience which was good for career thoughts."

"It is very practical and interesting and it's important to combine real life study (proposal) with class."

"Made me more aware of the realities of observational astronomy."

Comments and suggestions

Eleven respondents stated that the research and class activities were the highlight of the course, with a couple of respondents stating, this course "clearly portrayed what the future may hold in terms of grad school and research, provided a good foundation of research skills," and, showed "how vital working in groups was to research in this field." Respondents suggest making sure all course components connect and clarifying goals.

ASTR 680- Astronomical Techniques

August – December 2016 **San Diego State University, CA, USA** **7 participants**

ASTR 680: Astronomical Techniques is an undergraduate course offered by San Diego State University. This is an introductory course to data acquisition and analysis used in astronomy and astrophysics. Students utilized the Mount Laguna Observatory, which is part of the GROWTH network, to learn the operations of the telescope and to gain familiarity with astronomical tools.

Students will be able to…

- Operate the research telescopes at the Mount Laguna Observatory.
- Process data using student-developed code and analyze data to produce new astrophysical measurements.
- Produce written and oral reports on their work.

Demographics of survey respondents

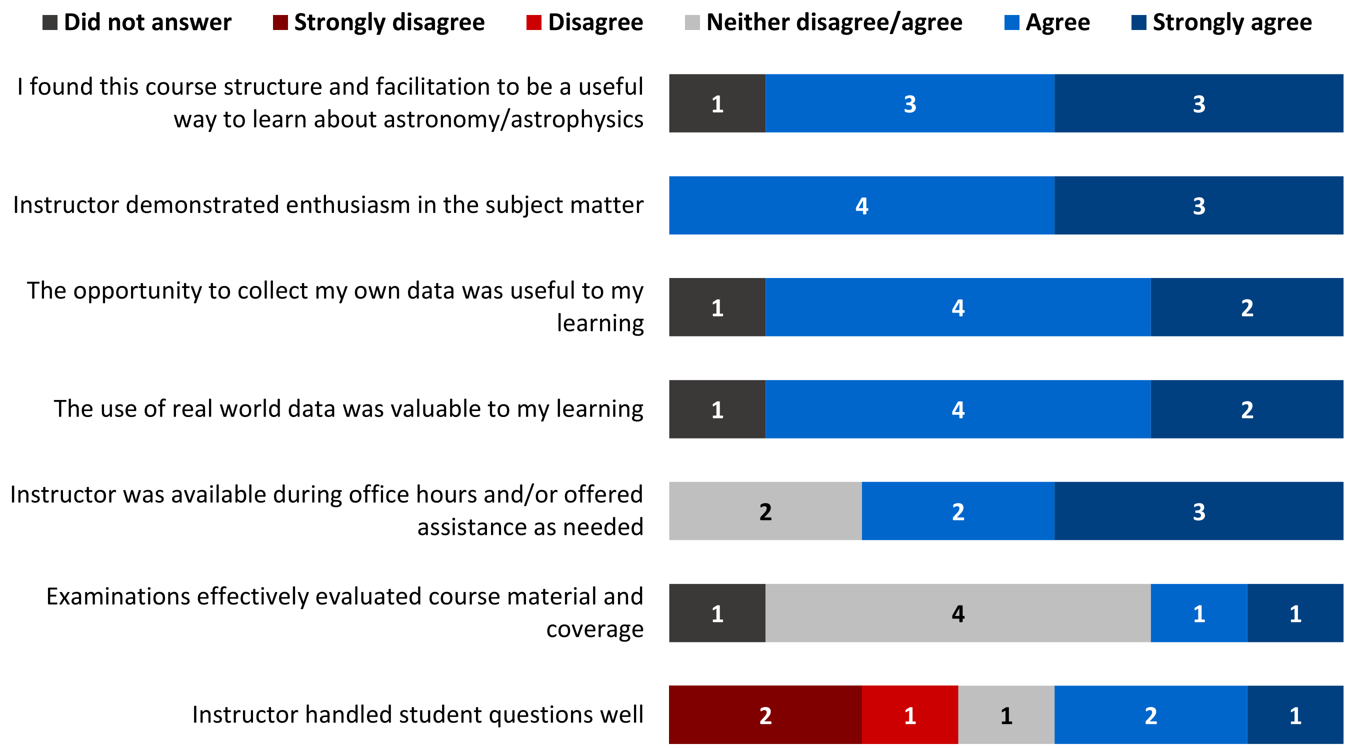
- All seven participants completed the course evaluation, for a 100% response rate.
- Two out of seven participants were female, four were male, and one did not specify his/her gender.
- Three of the seven participants were white/Caucasian, one was Asian, two were Hispanic or Latino, and one did not wish to specify.
- Three were first-generation college students.
- Six of the participants were in STEM majors (all six in astronomy). One did not specify.

Key findings and recommendations

Finding		Recommendation
All participants reported that they *agreed* or *strongly agreed* that **"using real world data was valuable to their learning" and "collecting their own data was useful to their learning."**	→	The instructor should continue to make these a cornerstone of the course and, perhaps, include a more in-depth investigation of the data.
Most participants stated that the analysis and coding activities were the highlights of the course.	→	Future iterations of the course should continue to focus on developing skills that will be used in future research.
Five out of six participants reported that the course had increased their interest in pursuing further studies or a career in astronomy or astrophysics.	→	The instructor could focus more on skill building and hands-on work with the tools and instruments to further bolster student interest.

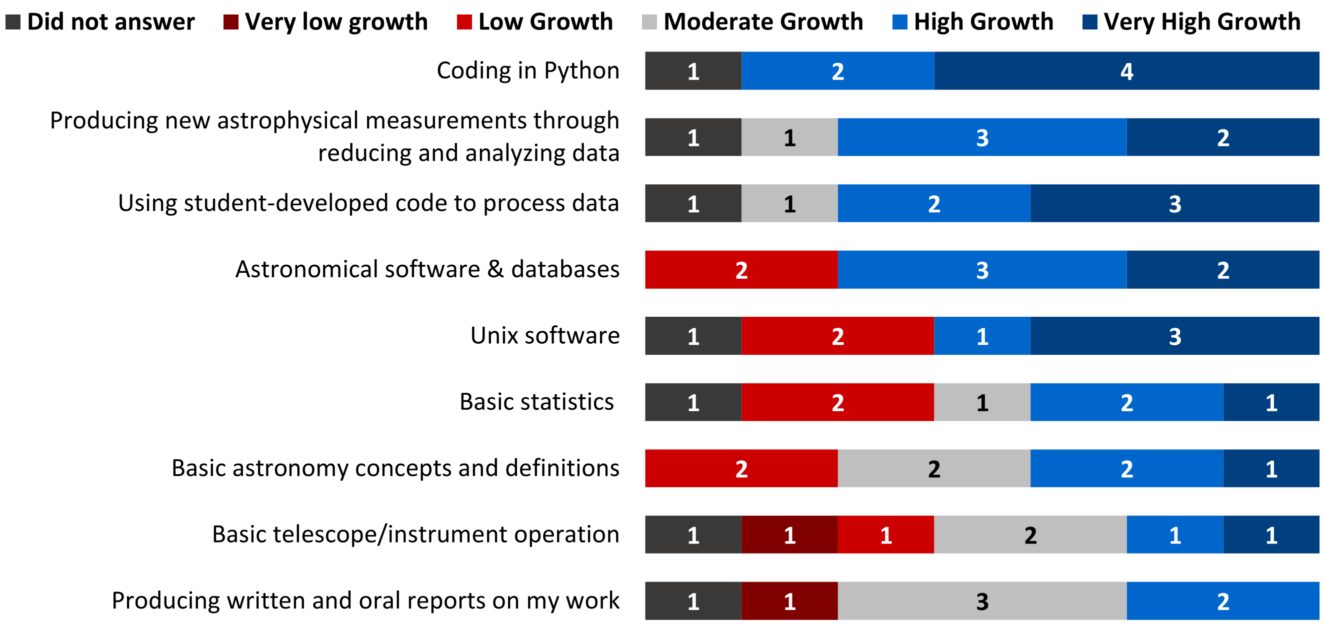
Course effectiveness

Participants rated their agreement in seven areas on a scale from 1-5, 1 = *strongly disagree* and 5 = *strongly agree.* Three out of six participants *strongly agreed* that the course structure and facilitation were useful in learning about astronomy/astrophysics. Three participants *disagreed* or *strongly disagreed* that the "instructor handled student questions well." Most participants *neither disagreed nor agreed* that the "examinations effectively evaluated course material and coverage," indicating this could be an area of improvement.



Course outcomes

Participants rated their growth in nine skill areas on a scale from 1-5, 1 = *very low growth* and 5 = *very high growth.* All participants reported *high* or *very high growth* in their knowledge and skills related to "coding in Python." Participants reported the least growth in their knowledge of all basic skills: "basic statistics," "basic astronomy concepts and definitions," and "basic telescope/instrument operation." Given that there is no baseline of participants' knowledge, it is difficult to know if the low growth was due to respondents already feeling knowledgeable, or because respondents actually needed more support in these areas.



Influence on educational and career trajectories

Participant responses to five questions about their educational and career trajectories indicated that:

- **5** had an increased interest in pursuing further studies or a career in astronomy or astrophysics.
    - While the participants gave varying reasons as to why the course increased their interest, several of the comments focused on skill and confidence building. Participants' comments are shown below.

> "I became much more involved in the "Dirty Work" of data analysis. I started the class highly unconfident of my abilities to complete such tasks."
>
> "The course has taught me a lot about the professional world of an astronomer."
>
> "This course has affected my interest in a positive way, such that it has solidified my desire to work in a STEM related field."
>
> "It helped prove to me that I'm capable."
>
> "It has helped me discover in what area of astronomy I could like to focus my career/studies."

Comments and suggestions

Four of the participants stated that the analysis and coding activities were the highlights of the course, with a couple of participants stating they gained skills that can be applied to research and work in astronomy/STEM. Participants suggest that instructors provide a review of basic math, such as more information on Bayesian statistics and Photometry, as well as practice with writing a grant proposal.

2016 GROWTH Social Network Analysis (SNA)

October – December 2016 **Baseline SNA** **22 participants**

Social network analysis (SNA) is a tool for understanding and mapping complex networks within systems of individuals or organizations. Project participants were asked to complete a survey wherein they indicated who they collaborated with and how. This GROWTH SNA displays those who completed the survey (n=22) and those that did not complete the survey, but were selected by the survey completers (n=27). If a participant did not complete the survey and was not selected by anyone else as a collaborator, they do not appear in the network (n = 9). In addition to specifying if collaborations occur, respondents indicated the type of collaboration, such as publications, presentations, and proposals. Respondents were also asked to identify facilitators and barriers of collaboration in the project and their opinions on the importance of collaboration as part of the GROWTH project.

The more project participants that complete the survey, the more accurate and complete the network maps are. The current SNA survey was completed by 22 of the 58 project participants (38%) and therefore should be interpreted with caution given that less than half completed the survey. The following analyses were conducted and are included in this section of the report:

Analysis 1: GROWTH collaboration network

Displays the project members and the collaborations between them. This network diagram is useful in that it allows for the simple display of connections in the network and the interconnections between members of the project. However, given that the collaboration network is more nuanced, two additional analyses were conducted. These analyses are detailed below and their corresponding diagrams are featured within this report.

Analysis 2: collaboration eigenvector

Displays project participants' collaborations with one another, with an emphasis on the influence individual members have on the collaboration network.

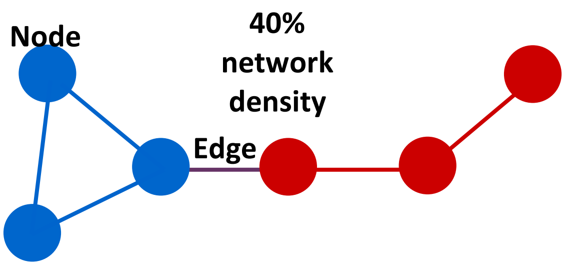
Analysis 3: collaboration betweenness

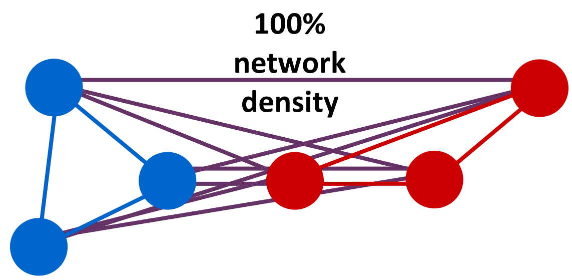
Displays project participants' collaborations with one another, with an emphasis on the bridges between collaborators.

Key SNA definitions

- Nodes represent participants (GROWTH members).
- Edges represent the connections between the members.
- Density of a network is the percentage of connections that have been made out of all possible connections.

Examples of these terms are below:





Partner university color coding

In all SNA diagrams, each partner institution has been designated a color, and that color coding is shown below along with the number of respondents from that institution:

- California Institute of Technology (Caltech) **-7 respondents**
- Humboldt University of Berlin (Humboldt University) **-2 respondents**
- Indian Institute of Astrophysics (IIA) **-1 respondent**
- Inter-University Centre for Astronomy and Astrophysics (IUCAA) **-1 respondent**
- Los Alamos National Laboratory **-0 respondents**
- NASA **-0 respondents**
- National Central University (NCU) **-1 respondent**
- Stockholm University **-2 respondents**
- Pomona College **-1 respondent**
- San Diego State University (SDSU) **-2 respondents**
- Tokyo Institute of Technology (Tokyo Tech) **-1 respondent**
- University of Maryland, College Park (UMD) **-4 respondents**
- University of Wisconsin, Milwaukee (UWM) **-0 respondents**
- Weizmann Institute of Science **-0 respondents**

Please note:
Diagrams within this report are created based on responses to the SNA survey. Participants who did not respond to the SNA survey and were not selected by anyone else as a collaborator are not represented in the diagram.

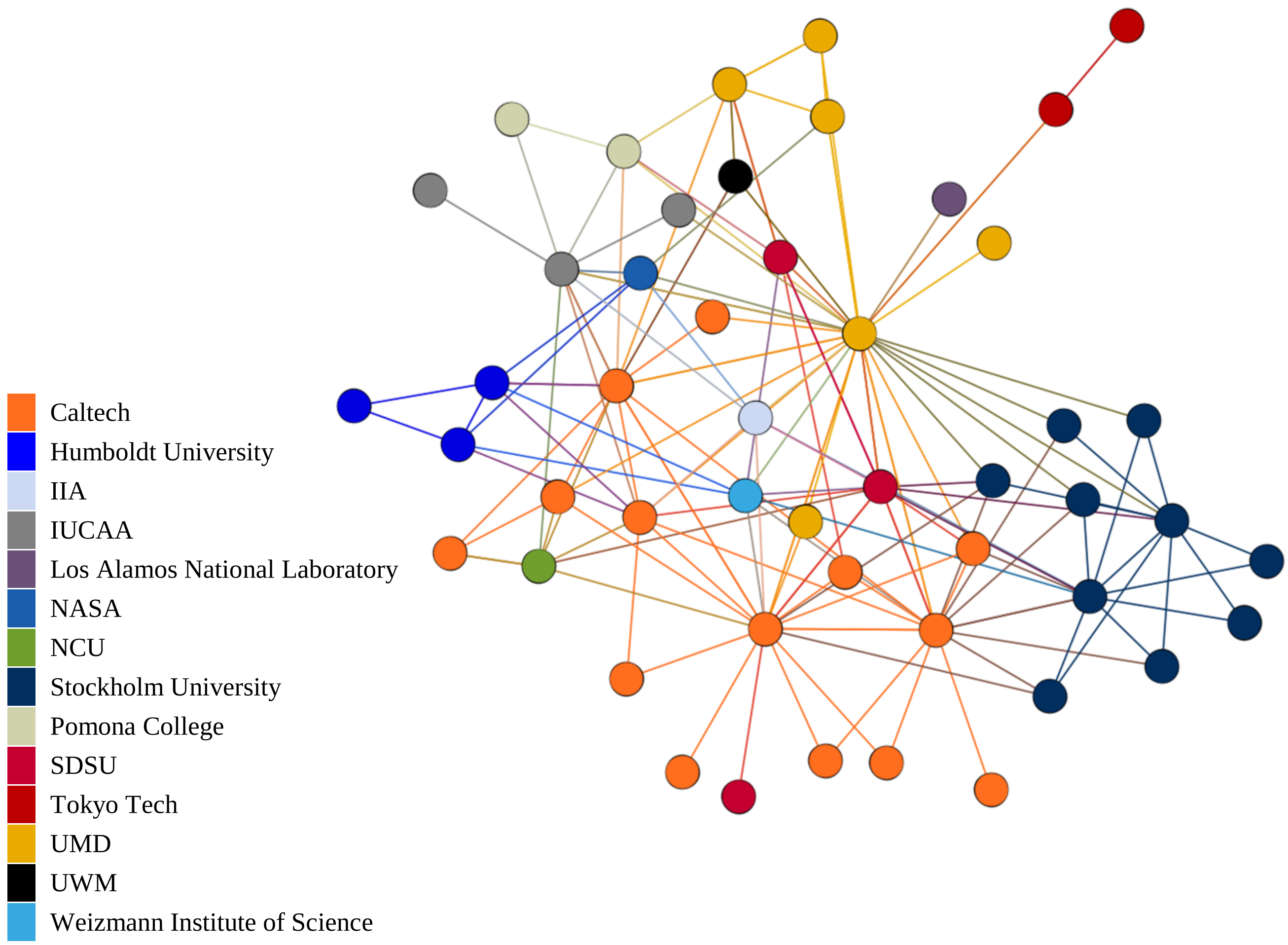
Analysis 1: GROWTH collaboration network

Respondents indicated whether they were currently collaborating with other project members. Collaboration is viewed as research and theoretical efforts, publications and presentations, and education related efforts. Participants (members) are placed in the network based on their connections with other members. The more central a member is in the network, the more lines he/she has connecting to other members and the more he/she serves as a connector between others.

Lines connecting members are color coded based on colors of the two connecting members, for example, a collaboration between members from SDSU (which is red) and UMD (which is yellow) will be a shade of orange. The entire GROWTH collaborative network contains 49 nodes (members) and 151 edges (lines indicating connection). The network has a density of 0.113, which indicates that 11.3% of the possible collaborative connections in the network have been made between members.

Key findings

- Members tend to collaborate more with members of their own institution.
- Caltech and Stockholm University account for 49% of the members of the collaborative network.
- 86% of the members of the network have more than one collaborative relationship.
- On average, respondents reported having three collaborations.

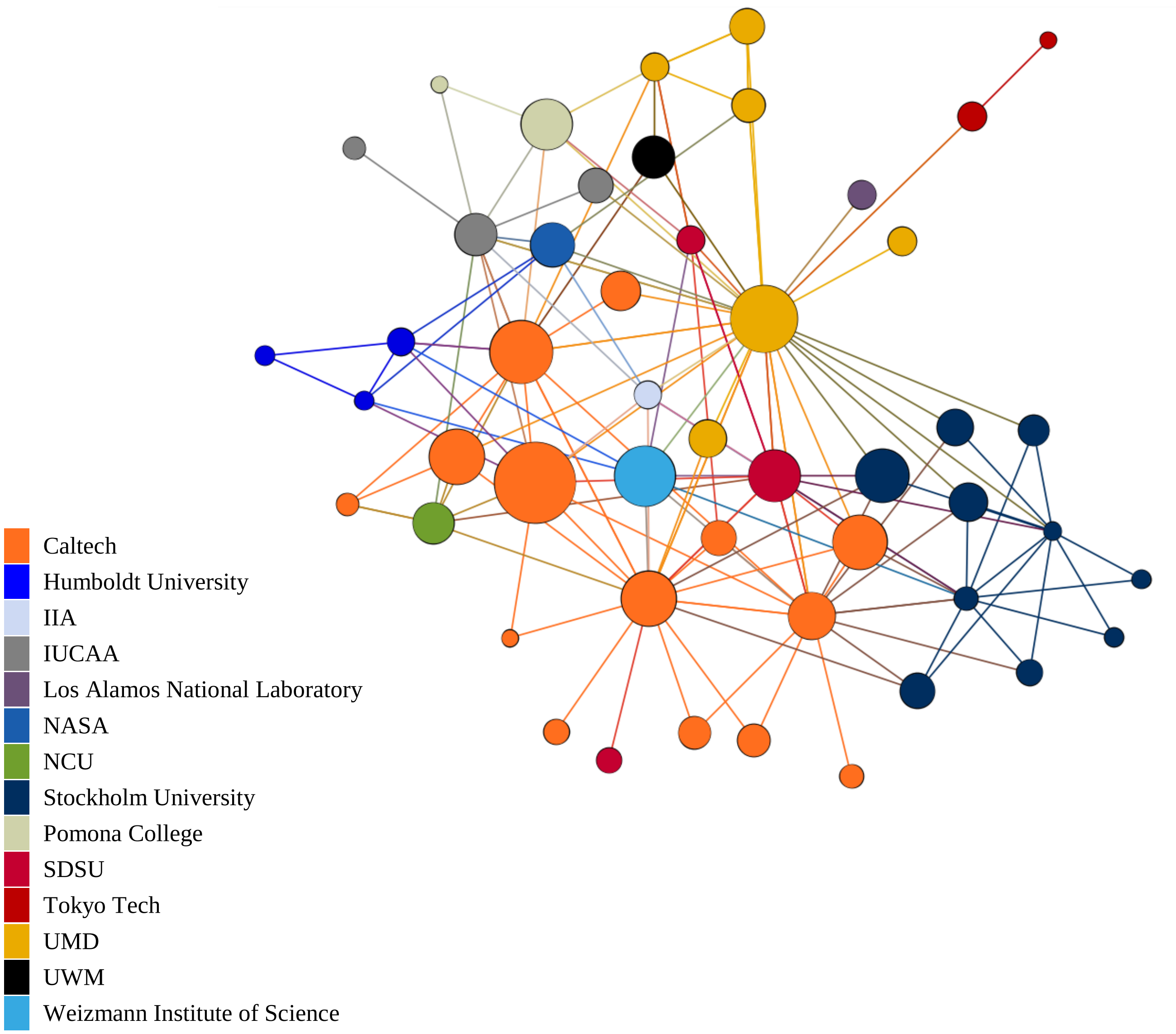


Analysis 2: collaboration eigenvector

The **Eigenvector score** is an effort to find the most central members within a network. A member's Eigenvector score suggests the importance they may have in the network. If a central figure changes their position or involvement in the project, there will be greater fluctuations in the network. The larger a member is in the diagram, the more influence they have on the network.

Key findings

- Most of the members with the highest Eigenvector rating are from Caltech. These members are integral to the functioning of the system.
- After the Caltech project members, members from Stockholm University and the UMD have the highest Eigenvector values and, therefore, influential impact on the system.
- Peripheral members are those on the outside edges of the network. These nodes have lower Eigenvector scores and the least influence on the network. Most of the members are undergraduate students or postdocs.

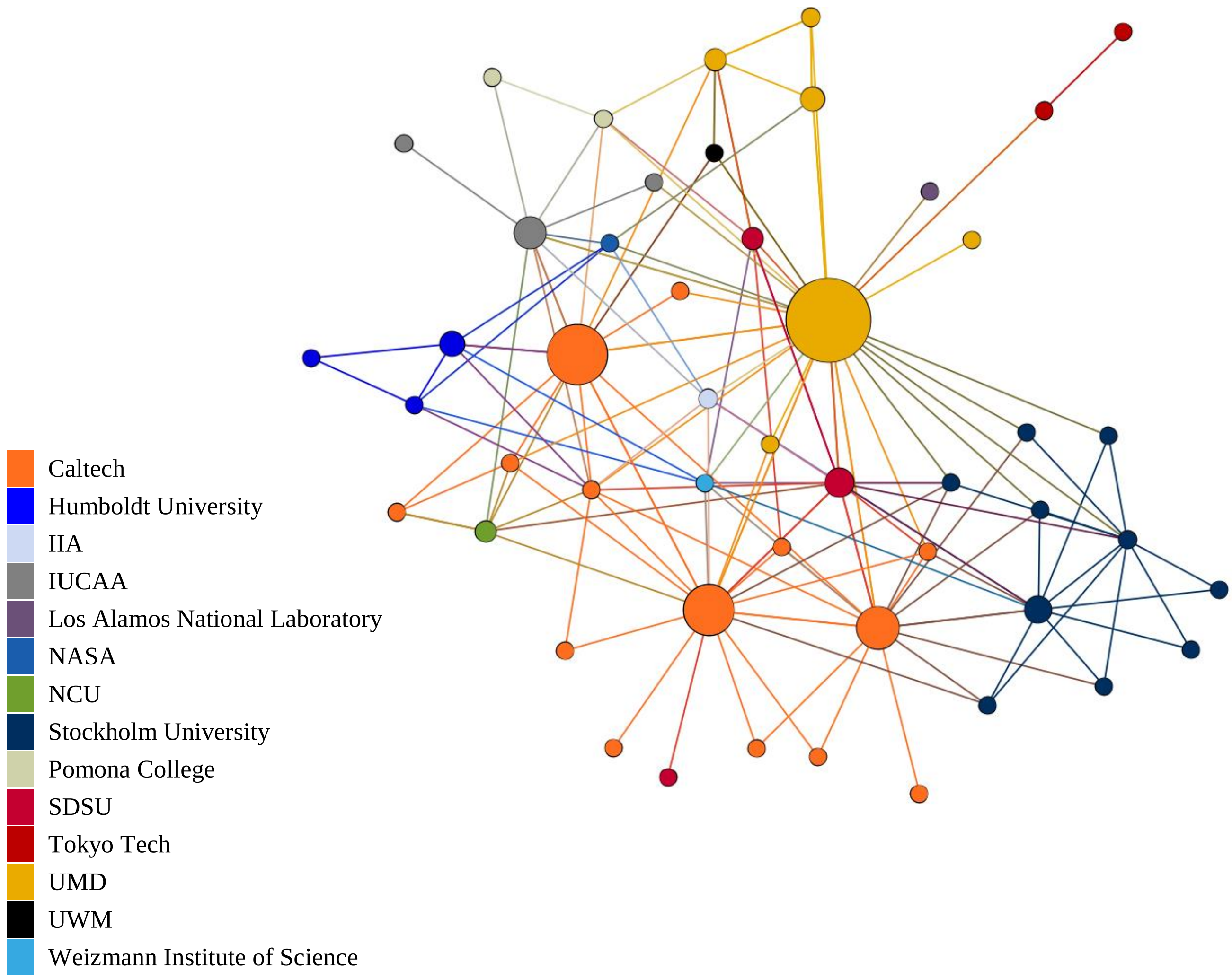


Analysis 3: collaboration betweenness

Betweenness is the measure of how often a member appears on the shortest paths between members (i.e. how often a member appears as a link between two other members). The larger a member is in the diagram, the more often he/she is a connector between other members. In other words, the larger a member's circle in the diagram, the more often that individual appears as a link between two other members and can serve as an information channel between various members of the project. These individuals can also affect the network if they change involvement in the project; therefore, it is important to think about who these individuals are, and others in their area of study/institution that could serve in that role were they to leave or change positions.

Key findings

- The betweenness measure is also an indicator of the "gate-keepers" of knowledge and collaborations. A gate-keeper is an individual that serves as a bridge between various clusters in the network.
- Four project participants were found to be the gate-keepers for the network. These individuals scored the highest in betweenness values for the network.
    - Three of the four members are from Caltech and the other is from the UMD.



Types of collaborative efforts among GROWTH participants

The collaborations formed in the GROWTH network consisted of three types: research, publications and presentations, and education. Respondents were asked to identify how they collaborate with other project members and describe these collaborations. Most of the collaborations in the project focus on research/theoretical efforts and publication/presentation efforts; however, almost three-fifths of respondents (58%) reported that they planned on enhancing their level and type of collaboration in the future.

Area	Description
Research and theoretical efforts	• 115 collaborations related to research and theoretical efforts were described, including telescope operation and sharing data and instruments. Some research collaborations involved advising students/mentoring students (13%).
Publications and presentation efforts	• 121 collaborations related to publications and presentations were described. Of these, 74% were journal articles for academic publication. Other publication/presentation collaborations included: ○ Observations (5%) ○ Conference papers/posters (4%) ○ Telescope proposals (2%) ○ New grant proposals (4%) ○ Research papers in preparation (2%) ○ Other (8%)
Education and related efforts	• 35 collaborations related to education were described. Out of the 35 reported, no single type was reported by a majority. The types of education collaborations included: ○ Teaching approaches and strategies (17%) ○ Mentoring and advising students' academically (17%) ○ Scanning new candidates (17%) ○ Development of new course materials (11%) ○ Course improvement (9%) ○ Other (29%)

Facilitators of collaboration

Most respondents reported that meetings, especially telecons and the GROWTH conference, were beneficial to their collaborative efforts. These activities were for a defined period of time and allowed for participants to conduct research, share ideas, and plan for upcoming courses. Graduate and undergraduate students shared that mentors, internships, and GROWTH staff helped facilitate their collaboration.

Barriers to collaboration

Respondents reported not having enough time to work with other project members, or on their own research. Respondents reported that communication issues arose due to the global nature of the project; specifically, challenges with scheduling meetings due to multiple time zones.

Recommendations related to network analysis

- **Project leads should start conceptualizing the ideal GROWTH collaboration network.**
  - Consider the following: What does it look like? Where are relationships concentrated and where is concentration less important? There are additional analyses that can be conducted once the ideal network has been conceptualized.
  - Since many members of the project have been collaborating frequently prior to the project's inception, project leadership should assess if any changes in the network are necessary or desired to further the goals of the project.
  - Assess what resources and/or skills are needed to manage the network/improve the functioning of the network. This can be accomplished by asking the following questions.
    - Whose role is it?
    - Are there costs associated with the management of the work?
    - What skills and expertise are needed?

- **The results of the SNA should be utilized to understand how collaborations in the network can be modified and how to start planning new project components.**
  - The collaboration eigenvector analysis shows the peripheral members of the project having little influence on the system.
    - Encourage collaboration with and integration of the peripheral members of the system, as they represent undergraduate students and postdocs.
    - Although peripheral members are not highly connected to the network, they can represent important resources for new information not currently available to the network.
    - As the project progresses, it will be important to examine how information is retained and transferred between members and institutions in the event a central member leaves the network.
    - Share the barriers and facilitators of collaboration at the management team meetings. Given that scheduling was listed as a barrier, brainstorm ways to address communication barriers among international partners.
  - The collaboration betweenness analysis shows four main individuals that serve as a bridge between various clusters in the network.
    - Ensure that bottlenecks of information do not form and information does not become concentrated among small clusters of members.
    - Encourage communication between members through more interactive and collaborative settings to attempt to alleviate the concentration of knowledge and connections.

- **Project leads should continue to work with external evaluators to plan for continued evaluation of the collaboration network.**
  - To assess achievement of Goal 3 (building collaborative networks), the Social Network Analysis should be conducted annually to assess trends and network progress over time.
  - Project leads and administration should encourage more participation of project members in the social network survey, to obtain a more holistic representation of project collaboration.